CALIFORNIA
ENERGY
COMMISSION

2004 Annual Review of the PIER Program Volume 2 – Residential and Commercial Buildings End-Use Efficiency Project Summaries

STAFF REPORT

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2008 Building Efficiency Standards Research

Contract #: 500-04-006
Contractor: Bruce Wilcox
Contract Amount: $965,053
Contractor Project Manager: Bruce Wilcox (510) 528-4406
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The goal of this project is to carry out research that will support the development of California's 2008 Residential Building Energy Efficiency Standards. This project will develop a computer model of residential attics that accounts for the heating and cooling performance of combinations of efficiency measures of interest, and is usable for both standards development and compliance. This project will also develop an hourly computer model for indirect-direct evaporative cooling systems usable for both standards development and compliance under the time-dependent valuation (TDV) approach. This model will be used to prepare a standards compliance option to allow full credit for indirect-direct evaporative cooling under the 2005 Standards. Finally, this project will provide paths for the California Energy Commission to move forward in both the Building and Appliance Standards to achieve significant air handler fan energy savings in both new and existing California homes.

This project supports the PIER Program objective of:

- Improving the Energy Cost/Value of California's Electricity by providing research results that will facilitate changes to the Building Energy Efficiency Standards. These building standards directly impact the energy efficiency of all new homes in California.

Proposed Outcomes:

1. Introduce a new residential attic model for use in standards development and compliance.
2. Produce a standards compliance option for indirect-direct evaporative cooling systems.
3. Develop building standards and appliance standards approaches for air handler fan efficiency.

Project Status:
This project began in November 2004. Experts for each technical area have committed to participate in the project and a Project Advisory Committee is being formed. Existing attic component models are being evaluated. The field survey of air handler fan efficiency has begun. The project is expected to be complete by December 2006.

Building Commissioning - Innovation to Practice

Contract #: 500-04-001
Contractor: Portland Energy Conservation, Inc.
Subcontractors: Lawrence Berkeley National Laboratory
Contract Amount: $375,650
Match Amount: $477,650
Contractor Project Manager: Amanda Potter (503) 595-4474
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
This State Technologies Advancement Collaborative (STAC) program sets out to develop and introduce the market application of innovative, yet practical functional performance testing and diagnostic tools and training by commissioning agents and building owners in California, New York, Texas, Nebraska, Iowa, Oregon, Washington, Idaho, and Montana. The feedback obtained from initial deployments will be used to improve these commissioning products, obtain improved information about the benefits and costs of adopting these commissioning products and services, and expand the market awareness of the benefits of commissioning.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing tools and training for building commissioning providers that will translate into energy savings and improved building performance benefits to the commercial building industry.

Proposed Outcomes:

1. Produce an enhanced Functional Test Guide for Air Handler Systems (FTG), including additional functional tests and useful information for commissioning providers performing the tests. The current version of the FT Guide (http://eetd2.lbl.gov/ftg/ftg-reg.php) will be used as the basis for the enhancements.
2. Develop training curriculums based on the FTG and conduct training to commissioning providers in each partner state.
3. Develop a Functional Testing Checklist Tool that will allow the user to enter general project information such as system type, building activity, and level of testing budget and then generate a checklist of functional tests that should be done for those particular systems in the operating environment indicated.
4. Develop a Functional Test Data Analysis Tool that will use a library of data analysis routines to analyze test data, assess performance of the unit, and identify the likely causes of failure.
5. Develop and demonstrate an advanced prototype version of an Automated Building Commissioning Analysis Tool (ABCAT). ABCAT will become a cost-effective, user-friendly, web-based tool for online detection and diagnostics of building performance and will project the economic benefits from correcting degradation of the building systems.

Project Status:
The FTG is being piloted by functional test providers in real building applications. Additional functional tests, as well as other needed improvements to the FTG, are being identified through this process. Software specifications for the Functional Test Data Analysis Tool are being drafted. The ABCAT prototype engineering and software specifications have been drafted. The project is expected to be complete by July 2006.

Classroom HVAC: Improving Ventilation and Saving Energy

Contract #: 500-03-041
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $744,000
Match Amount: $473,000
Contractor Project Manager: Michael Apte (510) 486-4669
Commission Contract Manager: Brad Meister (916) 653-1594
Status: Active

Project Description:
This project will develop, evaluate, and demonstrate a very practical heating, ventilation and air conditioning (HVAC) system for classrooms that consistently provides classrooms with the quantity of ventilation in current minimum standards, while saving energy, and reducing HVAC-related noise levels. The ultimate goal is to provide the specification of this system to the public domain, and promote its acceptance into the market through interaction with key stakeholders in California school facilities. PIER is partnering with the Bard Heat Pump/Air Conditioner manufacturer to improve the energy, ventilation and noise performance of their existing units that have dominant market share in California schools.

This project supports the PIER Program objectives of:

- Improving the environmental, public health, and safety of California's electricity by improving indoor environmental quality (IEQ), health, and learning in classrooms (CRs) using electrically powered HVAC systems.
- Improving the energy cost/value of California's electricity by maximizing the benefits of electricity use for ventilation.

Proposed Outcomes:

1. Quantitatively show that energy consumption reductions and IEQ improvements of the newly developed HVAC system under real conditions match those intended by design and those observed in laboratory tests. This is at least a statistically significant 30% decrease relative to the 10 SEER system or, by inference, a 10% decrease compared to the 12 SEER system.
2. Show quantitatively in the laboratory and verify in the field that, with the newly developed HVAC system, there is a reduction in sound power of more than 50%.
3. Demonstrate that the newly developed HVAC system meets general physical dimension and integration characteristics suitable for mounting on new and existing relocatable classrooms in California.
4. Show quantitatively that the new HVAC system meets 100% of ASHRAE 62 Standard outside air supply flow and can provide it continuously. Demonstrate that the TITLE 24 pre-occupancy ventilation requirement is met by the new HVAC system.
5. Demonstrate that the new HVAC system maintains indoor carbon dioxide (CO_2) levels below 1000 parts per million (ppm) and provides thermal conditioning at air velocities and temperatures that meet ASHRAE 55 thermal comfort standards.
6. Demonstrate the energy and IEQ capabilities of the new HVAC system in a set of occupied CRs in two distinct climate zones in California.

Project Status:
Laboratory testing has been completed on the new HVAC system. The field study plan is also complete, and installations in demonstration schools are underway. A methodology is being developed to estimate the statewide energy savings potential of these HVAC system improvements in California schools. This project is expected to be complete in December 2006.

Cool Ducts

Contract #: 500-02-004 **Work Authorization #:** UC MR-030
Contractor: Lawrence Berkeley National Laboratory
Project Amount: $346,563
Contractor Project Manager: Hashem Akbari (510) 486-4287
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
The purposes of this project are to investigate the benefits of cool-coating above-roof ductwork, to investigate the benefits of cool roofs on rooftop AC unit performance, to recommend changes to the Title-24 energy code to reflect this information, and to conduct workshops to publicize the results.

This project supports the PIER Program objectives of:

- Improving the reliability, quality, and sufficiency of California's electricity by quantifying the benefits of cool roofs to rooftop AC performance.
- Connecting to near-term market applications by encouraging the cool coating of rooftop ductwork by demonstrating its energy benefit.

Proposed Outcomes:

1. Quantify the energy benefits of the cool coating of ductwork.
2. Quantify the energy benefits of cool roofs to rooftop AC unit efficiency.

Project Status:
The field testing on the cool coating of ducts was completed late in the cooling season of 2004. Data analysis is in process. Field testing of the effect of cool roofs on rooftop AC performance missed the 2004 cooling season, but a field site was secured. Testing will take place summer of 2005, and following that data analysis will be done. If results are favorable the project will proceed to recommend Title 24 updates and conduct workshops.

Energy Efficient UC/CSU Campuses

Contract #: 500-02-004 **Work Authorization #:** UC MR-022
Contractor: California Institute for Energy and Environment (CIEE)
Project Amount: $3,000,000
Contractor Project Manager: Karl Brown (510) 287-3330
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The PIER Buildings Program has conducted substantial R&D for building energy systems like those on college campuses. These efforts have produced technologies and practices ready for demonstration in order to validate performance in actual building applications. These R&D efforts have also produced pre-commercial research products that are in need of larger scale installations to better understand cost-effectiveness and market acceptance. The campuses that will participate in the University of California/California State University/Investor Owned Utility (UC/CSU/IOU) Energy Efficiency Program are ideal candidates for installing these pre-commercial research products and demonstrating emerging technologies developed in the PIER Buildings Program. This partnership will also create a unique opportunity for the PIER Buildings Program to employ California college campuses as a test bed for continuing current research in real-world environments. The UC/CSU/IOU Energy Efficiency Program is funded by a $12 million multi-year program award from the California Public Utilities Commission (CPUC). This program will improve the energy efficiency of California college campuses by implementing energy efficiency retrofits, facility retro- and continuous-commissioning, including extensive permanent energy monitoring at the building and subsystem level, and energy efficient education and best practices development and training. The UC/CSU/IOU Energy Efficiency Program Managers, as well as the campus facility managers participating in the program, will benefit from a greater understanding of the PIER Buildings Program research products that can realize energy savings in the short term, as well as emerging technologies that can be demonstrated now to achieve longer-term energy savings. Targeted briefings on the PIER Buildings research products will help the UC/CSU/IOU Energy Efficiency Program identify and deploy advanced technologies and practices.

This project supports the PIER Program objectives of:

- Improving the Energy Cost/Value of California's Electricity by transferring PIER efficiency technology and practices to the California university campus sector, demonstrating PIER efficiency technology and practices in a richly monitored institutional facility environment, and gaining new knowledge regarding the efficiency of institutional and commercial facilities through field R&D in PIER subject areas.

Proposed Outcomes:

1. Demonstrate PIER efficiency technologies and practices in institutional facilities, capturing the benefit of the rich monitoring environment created by the CPUC funded UC/CSU/IOU Energy Efficiency Program.
2. Use PIER technology and practices to increase the value of monitoring installations, associated retro- and continuous-commissioning efforts, energy-efficiency education, best practices development and training, and other aspects of the CPUC public goods-funded UC/CSU/IOU Energy Efficiency Program
3. Use the unique monitoring environment to gain increased knowledge about PIER technologies practices, as well as institutional facility operations, through field RD&D in PIER subject areas.

4. Disseminate information gained from this program to the California university and college campus sector, other California educational and institutional sectors, and the California commercial sector as applicable.

Project Status:
A dozen building energy efficiency technologies developed with PIER funding have been selected for demonstration by fourteen California college campuses. Demonstration and case study plans are currently under development. These technologies should be installed in campus demonstration sites by the summer of 2005. Energy efficiency training and education curriculum for campus facility managers and project management staff are currently under development. This project is expected to be complete by June 2006.

Final Phase Research - HPCBS Program

Contract #: 500-03-022 **Project #:** 1-4
Contractor: Department of Energy - Lawrence Berkeley National Laboratory
Contract Amount: $1,306,951
Match Amount: $725,000
Contractor Project Manager: Stephen Selkowitz (510) 486-5064
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The goal of this research program is to develop and demonstrate advanced tools, technologies and building systems that will economically deliver significant energy and peak demand savings and enhance the indoor environment of commercial buildings in California, all with low real and perceived risk. Lighting and HVAC systems are the most energy intensive end uses in commercial buildings and are directly addressed by program activities. There are three technical projects in this research program:

- Benchmarking California Buildings.
- Advancing Digital Lighting Controls.
- Performance Monitoring in Large Commercial Buildings.

The Benchmarking project will be particularly useful to owners and designers in both assessing current building performance and evaluating targets for new construction. The Digital Lighting Controls project will provide solutions for both new and existing buildings that improve energy utilization and reduce consumption and demand while enhancing the indoor luminous environment. The Performance Monitoring project will provide the capability for owners and facility managers to accurately track building energy performance on an ongoing basis and support diagnostic and corrective action if needed to maintain or improve energy performance levels. All of the projects will be conducted with industry partners who not only will share project costs but also are directly involved in deployment and implementation activities.

This project supports the PIER Program objective of:

- Improving the Energy Cost/Value of California's Electricity by accelerating the introduction of better benchmarking and monitoring tools and more efficient and reliable equipment and methods to heat, cool, ventilate and light the commercial building stock in California, including both new and existing buildings of virtually all occupancy types, and in all California climatic zones. Energy use reductions will be accompanied by summer peak load reductions and demand response capabilities that can be employed throughout the year.

Proposed Outcomes:

1. Benchmark California Buildings.
    - Create a tool that can be used by designers and school operators to better understand relative energy performance of schools in California.
    - Demonstrate the value of the tool in understanding relative energy performance of specific buildings.
    - Commercial suppliers of Energy Information Systems, EMCS suppliers and other companies delivering energy services incorporate the Benchmarking tool into their tools and services.

- Complete recommendations for California commercial building benchmarking tools and datasets, including a comprehensive, multi-year plan for benchmarking commercial buildings in California.

2. Advance Digital Lighting Controls.
   - Develop lighting system prototypes, and demonstrate the advantages of digitally controlled lighting systems to innovative property managers and other energy stakeholders.
   - Demonstrate that Integrated building equipment communicate systems (IBECS) control technologies can facilitate better market penetration for both existing analog controls as well as digital addressable lighting interface (DALI) systems.
   - Use field studies to demonstrate 30% energy savings potentials and 50% demand savings potentials for lighting systems with multiple control strategies.
   - After five years, IBECS technologies reach a market penetration rate of 20% of sales.
3. Monitor Performance in Large Commercial Buildings.
   - Demonstrate the value of performance monitoring to large building owners.
   - Develop a specification for energy-oriented performance monitoring capabilities for commercial buildings that can be implemented either as part of an EMCS, part of an Energy Information System (EIS), or as a standalone system.
   - Demonstrate building owner demand to monitoring system vendors, and these vendors maximize the energy-efficiency benefits of their responses to this owner demand.
   - Performance specifications are defined in a way that uses competitive market forces to optimize the price-performance system offerings to building owners.
   - Performance monitoring systems are employed by at least two large public building owners and one large private building owner.

Project Status:
Opportunities to integrate building energy performance benchmarking into market-specific energy efficiency outreach efforts and ongoing building monitoring applications have been identified. Collaborations with national and international energy benchmarking programs continue. This benchmarking research will directly aid the California Energy Commission's implementation of the Governors Executive Order S-20-04, which mandates that a benchmarking methodology be developed for California commercial buildings. Development and testing of digital lighting control components is underway. Collaboration continues with New York State Energy Research and Development Authority (NYSERDA) and the New York Times to demonstrate the functionality of digital lighting controls in their full-scale building mock-up. A draft specification for control systems capable of performance monitoring had been developed and is under review by industry experts. The Department of General Services is actively involved in this project, as they will demonstrate performance monitoring systems in state-owned buildings and also integrate the specifications into future construction and renovation projects. This program is expected to be complete in December 2005.

National Building Control Information Program

Contract #: 500-02-004 **Work Authorization #:** UC MR-034
Contractor: Iowa Energy Center - Iowa State University
Project Amount: $400,000
Contractor Project Manager: John House (515) 965-7345
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The Iowa Energy Center (IEC), an energy research, demonstration and education organization administered by Iowa State University, operates the National Building Controls Information Program (NBCIP). The NBCIP is a long-term, multi-sponsored program dedicated to improving the design and operation of building heating, ventilation and air conditioning (HVAC) control systems. The NBCIP has a mission of facilitating the adoption of energy efficient building control products through testing, demonstration, education and dissemination of product information. Through this project, NBCIP will assist the market transfer of PIER's controls-related research. This project includes complementary research activities by the Iowa Energy Center. First, the IEC will provide research support to the PIER Buildings program area by developing test methods and protocols, test data, and employing test facilities as appropriate to improve the R&D of controls-related products. Second, the IEC will undertake controls-related research activities that meet specific public interest criteria. It is anticipated that the results of these research activities will be incorporated into the NBCIP's information products in the future. This project also provides for the Energy Commission's participation on the Performing Institution's NBCIP Board of Directors for two years, expanding NBCIP's research efforts and incorporating appropriate PIER-funded research results into NBCIP's information products.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by facilitating the energy efficiency of buildings through the proper design and operation of HVAC control systems.

Proposed Outcomes:

1. Provide product testing reports, best-practices control strategies, application guidelines and building operation tutorials to the building industry to ultimately improve the energy performance of new and existing buildings.
2. Create test data, methods, and protocols and employ the test facilities at the IEC's Energy Resource Station as appropriate to support PIER's HVAC diagnostics research.
3. Undertake collaborative R&D projects to advance the state-of-the-art in building control system design and operation.

Project Status:
Work on this project is anticipated to start in the spring of 2005.

Phase Last Projects

Contract #: 500-03-030
Contractor: Architectural Energy Corporation
Subcontractors: Southern California Edison : Portland Energy Conservation, Inc. : New Buildings Institute, Inc. : Purdue University
Contract Amount: $2,935,240
Match Amount: $836,129
Contractor Project Manager: Vernon Smith (303) 444-4149
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
This contract involves 5 projects which were selected on the basis of technical potential and a visible path to commercialization. Most of them were developed from earlier PIER projects and revolve around the theme of improving heating, ventilation and air conditioning (HVAC) reliability. They are:

- Web-based automated diagnostics, to bring diagnostics to diverse, perhaps older, central plant systems by getting performance data out of the building to a centralized diagnostic processor. This centralized processing strategy eases diagnostic software maintenance and upgrades. The diagnostic service will be available to owners and HVAC service companies.
- Air handling units (AHU) and variable air volume (VAV) Diagnostics, to introduce rule-based diagnostics for AHUs and statistical process control methods for VAV boxes into the commercial realm of BACnet control manufacturers.
- Advanced package rooftop AC unit, to design and test reliability and efficiency enhancements for rooftop AC and work with national organizations such as the Consortium for Energy Efficiency to develop specifications for efficiency and reliability.
- Rooftop AC unit diagnostics, to develop, test and commercialize diagnostic technology for refrigeration cycle and outside air economizers for package air conditioners.
- Speciflow technology, to develop and commercialize an improved, economical technique for measuring airflow across control dampers.

This project supports the PIER Program objectives of:

- Improving the value of California's electricity by making air conditioning more efficient.
- Connecting to near-term market applications by having researchers work with industrial partners to commercialize technical developments.

Proposed Outcomes:

1. Web-Based Automated Diagnostics:
   - Create a web-based diagnostic system that detects significant faults in air handlers, chiller systems, and boiler systems.
   - Demonstrate the system in at least 3 commercial buildings.
   - Market the system as a commercial product.
2. AHU and VAV diagnostics:
   - Develop automated parameter adjustment to uncover problems but avoid false alarms.
   - Embed diagnostics in three to four commercial control manufacturer products.
3. Advanced Rooftop AC Unit:
   - Collaborate with major manufacturers to create advanced specification.

- Document benefits of improvements using life cycle cost analysis.
- Publicize project results by working with market transformation organizations.

4. Rooftop AC Unit Diagnostics:
   - Embed diagnostic methods into control offerings from one or more manufacturers.
   - Develop network systems to communicate equipment conditions to facilities personnel.
   - Deploy FDD-enabled unit controls and network systems in field demonstration.
5. SpeciFlow Technology:
   - Measure airflow more accurately and less expensively than existing technologies.
   - Market product through major equipment manufacturer.

Project Status:
The projects are actively underway and expected to be completed by June 30, 2006.

PIER Buildings Program Tech Transfer Initiative

Contract #: 500-03-005
Contractor: Platts Research and Consulting
Contract Amount: $256,546
Contractor Project Manager: Jay Stein (720) 548-5431
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Active

Project Description:
Produce and distribute four-page two-color research briefs and market the content to publications and other media editors.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by promoting PIER research.

Proposed Outcomes:

1. Produce and distribute 25 research briefs in PDF format.
2. Market the content of most of those research briefs to publications and other media editors.

Project Status:
A 2-color template has been developed for the research briefs. Ten briefs have been developed so far, and the first three will be distributed in Q1 2005:

1. Guide Illuminates Modular Skylight Well Design
   Publication Number: CEC-500-2005-045-PS
2. Design Guide: Big Savings on Small HVAC Systems
   Publication Number: CEC-500-2005-046-FS
3. Integrated Classroom Lighting System: Light's Great, Less Billing
   Publication Number: CEC-500-2005-047-FS

Residential Ventilation Standards Research

Contract #: 500-04-005
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $600,000
Contractor Project Manager: Max Sherman (510) 486-4022
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The purpose of ventilation is to provide acceptable indoor air quality and to enhance durability of systems and materials. This project will examine the relationship of ventilation to health and will be addressed by using American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) /American National Standards Institute (ANSI) 62.2-2003 and examining how this differs from current Title 24 Building Energy Efficiency code requirements. A key factor is the effect that any changes to the ventilation requirements in Title 24 have on energy use algorithms and compliance tools already in use by the California building industry. Another issue to be addressed is the potential for ventilation standards to consider peak load energy and the Time Dependent Valuation methodology implemented in the 2005 Standards. This project will examine potential credits and compliance paths for systems that allow load shifting or specifically target power reduction at peak load conditions in other ways.

The engineering issues related to providing acceptable indoor air quality without large energy penalties that will be examined in this project are:

- The use of occupant control, particularly window opening, and the effectiveness of this approach.
- Distribution of fresh air throughout a house.
- The role of unusual sources and source control.
- The role of air cleaning and particle filtration.
- Effects of poor outdoor air quality (e.g., particulates near busy roads or in rural communities).

The building ventilation requirements in the current Title 24 standard are primarily engineering based and, as a result, technical feasibility is likely to remain a key driver for these standards. Therefore this project will focus on existing ventilation strategies and technologies.

This project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by providing adequate indoor air quality at the lowest energy cost through ventilation standards for new homes.

Proposed Outcomes:

1. Review the state-of-the-art in residential ventilation standards and propose the minimum requirements that should be in the 2008 California Residential Building Energy Efficiency Standard in order to provide acceptable indoor air quality appropriate for new California homes.
2. Evaluate the performance of existing residential ventilation technologies for meeting the requirements determined in task 2. This evaluation will also investigate the energy and peak demand impacts of the various technologies.
3. Facilitate the adoption of the new ventilation requirements and development of appropriate algorithms and technical assistance for compliance tool software developers.

Project Status:
This project began in November 2004. Review of California-specific issues of ASHRAE 62.2-2004 is underway, as is a literature review of all other relevant ventilation standards and guidelines. The project is expected to be complete by December 2006.

BLDGS Active Projects from Previous Years

Advanced HVAC Systems for Improving Indoor Environmental Quality and Energy Performance of California K-12 Schools

Contract #: 500-03-003 **Project #:** 1 - 4
Contractor: Architectural Energy Corporation
Subcontractors: RLW Analytics, Inc. : Morton H. Blatt Utilization Consulting
Contract Amount: $234,475
Match Amount: $201,000
Contractor Project Manager: Vernon Smith (303) 444-4149
Commission Contract Manager: Brad Meister (916) 653-1594
Status: Active

Program Description:
The purpose of this program is to develop and demonstrate innovative HVAC systems for California schools that will improve indoor air quality, save energy, and reduce peak demand. This research effort will involve all the school-related institutions that govern or guide school building construction in California, including the California Department of Education, the Office of Public School Construction, the Division of the State Architect, the Coalition for Adequate School Housing and the Collaborative for High Performance Schools. The research contractors will work with major manufacturers to develop innovative systems that have energy and air quality advantages over conventional systems. They will demonstrate the energy performance and cost advantages of these systems, and develop and distribute design tools and related information to decision makers and school design professionals.

This programmatic contract supports the PIER Program objectives of:

- Facilitating the construction and operation of schools that are energy efficient, healthy and comfortable by developing and demonstrating innovative HVAC systems for California schools.
- Improving building affordability and value by providing design guidelines and objective product evaluation for cost-effective and energy efficient school HVAC systems.
- Reducing energy costs by promoting Thermal Displacement Ventilation technology, which will reduce both overall energy use and peak loads.

Proposed Outcomes:

1. Design a TDV HVAC system that requires 50% less fan energy and 33% less cooling energy than conventional HVAC systems.
2. Confirm or disprove manufacturer claims that UVC lights decrease cooling energy consumption by 10% and improve classroom indoor environmental quality (IEQ).
3. Disseminate research products widely to K-12 schools in California through the Collaborative for High Performance Schools (CHPS) and other stakeholder groups.

Project Status:
Project 1 (Administration):
The program kicked off in September 2003. A Program Advisory Committee has been established, and has met twice.

Project 2 (Thermal Displacement Ventilation):
The researchers developed and validated a Computational Fluid Dynamics (CFD) model of a typical California classroom. This model was then used to develop design guidelines for Thermal Displacement Ventilation (TDV) in schools. A demonstration classroom at Dry Creek

Elementary School in Roseville was constructed in summer 2004 and was monitored in Fall 2004. A second classroom demonstration using an improved design is planned for 2005.

Project 3 (UVC Lights):
Based on feedback from the Program Advisory Committee, this project will now conduct a field study instead of a statistical analysis of existing data to establish whether UVC lights are effective. The field study will be conducted summer 2005.

Project 4 (Market Connection):
A Technology Transfer Plan and Codes Action Plan have been completed.

Advancement of Electrochromatic Windows

Contract #: 500-01-023
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $639,386
Match Amount: $2,112,562
Contractor Project Manager: Stephen Selkowitz (510) 486-5064
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
Electrochromic windows can be electrically controlled to vary from clear to nearly opaque, and may become widely used if production costs can be reduced. The purpose of this project is to investigate energy and visual comfort attributes of these windows, and to develop control strategies and design guides. It includes energy simulations and includes construction of a test building with an instrumented heating, ventilation and air conditioning (HVAC) system for measuring thermal loads. The project is synergistic with Department of Energy (DOE) and US Department of Housing and Urban Development (HUD)-funded studies investigating long term performance and reliability characteristics of the windows.

This project supports to the PIER program objectives of:
- Improving electricity reliability and sufficiency by lowering energy use and peak electrical demands in buildings due to energy gain through windows.
- Providing greater choice for California consumers by lowering barriers to the emergence of a promising new technology in the marketplace.

Proposed Outcomes:
1. Develop design guides and acquire energy performance data that will become available to early adopters of electrochromic windows. This information will help to speed their acceptance and availability as mainstream products.
2. Investigate control strategies for producing a more satisfactory window-lighting system interaction.

Project Status:
The test facility on the LBNL campus was constructed, 3 sets of windows installed, and the thermal measurement system calibrated. Human factors tests were completed, and energy testing is going on. The project is expected to be complete by December 2005.

California Lighting Technology Center at the University of California, Davis

Contract #: 500-02-004 **Work Authorization #:** UC MR-018
Contractor: California Lighting Technology Center at University of California, Davis
Project Amount: $1,599,759
Contractor Project Manager: Patricia Harrison (530) 752-6411
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Active

Project Description:
This Work Authorization establishes the California Lighting Technology Center (CLTC) at University of California, Davis. The mission of the CLTC is to advance the application of efficient lighting technologies through research, education and outreach. The CLTC is a unique partnership between the National Electrical Manufacturing Association (NEMA), California utility companies, the California building industry, specific lighting corporations, the NRDC, the U.S. Department of Energy, and California universities and colleges to encourage the development and market adoption of energy-efficient lighting products.

The CLTC's mission is covered by six key activities:

- Encourage the application of energy-efficient, high performance lighting technologies.
- Develop new technologies through partnerships.
- Demonstrate new technologies.
- Transform lighting markets.
- Educate students, practitioners, manufacturers and the general public.
- Create a unique educational and applied research program through a dedicated industry-friendly facility.

This project supports the PIER Program objective of:

- Improving energy cost/value by fostering the application of energy efficient lighting, facilitating technology/market application technology, and developing lighting technology.

Proposed Outcomes:

1. Provide a facility, support infrastructure and the technical staff to demonstrate and test efficient lighting technologies in a controlled laboratory setting.
2. Develop the plan for governing and operating the CLTC.
3. Hire operations staff.
4. Perform full-scale simulations and demonstrations of actual lighting applications to increase the knowledge base of lighting practitioners and promote user acceptance and market transformation.
5. Identify and develop new, more effective and more efficient lighting technology applications that address commercial, industrial and residential lighting demands, and promote market awareness and acceptance in concert with the lighting industry.
6. Establish a broad-based outreach program that supports and works in harmony with existing utility energy centers and lighting programs.

Project Status:
The CLTC facility was completed and a Grand Opening ceremony was held in July, 2004. A draft R&D plan has been completed and an operations plan is under development.

Conceptual Design Energy Analysis Tool Phase 2

Contract #: 500-02-027
Contractor: GeoPraxis, Inc.
Contract Amount: $270,445
Match Amount: $598,125
Contractor Project Manager: John Kennedy (707) 766-7010
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
Currently, building designers rarely pay attention to their building design's impact on the energy use of the building until late in the detailed design phase of the project. At this phase in the project, an energy code consultant or engineer identifies opportunities to make the building more energy efficient. However, at this late stage of the design, many attractive energy savings options are already constrained due to earlier design decisions. This project is intended to give building designers feedback on building energy use early in the design process. This will enable them to make informed decisions on cost-effective design modifications with large energy impacts.

This project supports the PIER Program objectives of:

- Facilitating the construction and operation of buildings that are energy efficient, healthy and comfortable by enabling earlier feedback to architects on the energy implications of their designs.
- Improving building affordability and value by reducing the design costs associated with doing whole-building energy simulations.

Proposed Outcomes:

1. Develop a functional approach to providing architects with energy design tools in the early stages of design.
2. Integrate this functionality into market-leading Computer-Aided Design software packages.
3. Transfer the technology to the market via a free web service.
4. Disseminate information on the technology via seminars and training.
5. Establish gbXML as a non-proprietary standard for exchanging high-level design information between CAD tools and energy analysis tools.

Actual Outcomes:

1. Developed a functional approach to providing architects with energy design tools in the early stages of design.
2. Integrated this functionality into market-leading Computer-Aided Design software packages.
3. Transferred the technology to the market via a free web service.
4. Disseminated information on the technology via seminars and training.
5. Established gbXML as a non-proprietary standard for exchanging high-level design information between CAD tools and energy analysis tools.

Project Status:
This project is complete. The Green Building Studio web service can be accessed at:

⇒ www.greenbuildingstudio.com

Information about the building data exchange schema can be found at:

⇒ www.gbXML.org.

Cool Roof Colored Materials

Contract #: 500-01-021
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $1,970,000
Match Amount: $760,000
Contractor Project Manager: Stephen Weil (510) 486-5396
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
The purpose of this project is to develop cool colored roofing materials. Until now, a cool roof has meant a white roof. In order to address markets which demand darker colored roofs, this project involves development and field testing of roofing materials using special pigments which are highly reflective in the invisible infrared portion of the spectrum. These materials reject a significant amount of solar radiation but retain a normal colored appearance. Composition shingles, concrete and clay tiles, and metal roofing materials will be developed in cool colors. Short and long-term monitoring of the materials in various climate zones will help assess life cycle costs and susceptibility to degradation.

This project contributes to the PIER program objectives of:

- Improving the environment directly by reducing formation of photochemical smog and indirectly by lowering the need for electrical generation on hot summer days.
- Improving electricity reliability by lowering demand on peak days.
- Providing greater choices for California consumers by developing attractive roofing products that lower energy costs, improve indoor comfort, and are longer lasting.

Proposed Outcomes:

1. Affordable composition roofing materials which have solar reflectivity increased to 60 percent from the current 10-20 percent, reducing cooling-related energy and electrical demand by as much as 20 percent in the roughly 4.4 million California single-family detached homes with composition roofs.
2. Improvements in the generally superior reflectivity of concrete tiles which dominate new residential construction. This improvement will allow many more concrete tile products to qualify as cool roofs, an appellation that signifies at least 65 percent total reflectivity and 80 percent emissivity.
3. More cool roofing product choices and better performance in metal and clay tile products.

Project Status:
Products in all major categories (clay, concrete, composition, metal, wood) are currently being developed in collaboration with a broad range of industrial partners and tested for long-term performance in weathering test-beds across California. Some products have already entered the market. The project is expected to be completed by March 2006.

Cooling Solutions Collaborative Program

Contract #: 500-02-029 **Project #:** 2
Contractor: Gas Technology Institute
Project Amount: $150,000
Contractor Project Manager: David Kalensky (847) 768-0944
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
The purpose of this project is to conduct technology development and field test advanced natural gas cooling options. Gas cooling provides an alternative to electric powered commercial cooling, potentially mitigating peak electric demand in the high-growth areas of California's hot dry valleys. Applicable technologies include both absorption cooling and gas-engine-based vapor compression cycles.

This project supports the PIER Program objective of:

- Providing greater choices for California consumers by offering gas cooling options for the residential and commercial markets that can also reduce peak electric demand for all California consumers.

Proposed Outcomes:

1. Provide educational outreach to reach engineers in training who might not otherwise be exposed to less mainstream concepts of absorption cooling.
2. Build a website that will facilitate spreading information and provide links to equipment manufacturers.
3. Perform field demonstrations that will demonstrate the viability of the technology.

Actual Outcomes in 2003:

1. The websites were redesigned and moved to a hosting site to improve infrastructure security and reliability. Tutorial and case study sections were enhanced to include Building Cooling Heat and Power (BCHP) and steam-driven absorption chillers. Manufacturer links and materials were updated. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) studies on desiccants were completed and incorporated into the intranet access site.

2. Product Development and Field Testing.
   - Cooltec Chiller Testing at Linden Baker in Yorba Linda, CA and Newby Rubber Co. in Bakersfield, CA. Monitoring data indicated Unit #1 performed about 20% below expectations. Subsequent teardown indicted some refrigerant flow blockages.
   - DryKor TAC-10 Thermal Air Conditioner Field Demonstration.
     The objective was to field demonstrate DryKor's Beta Edition TAC-10 Thermal Air Conditioner, a 10 ton liquid desiccant dehumidification and cooling technology.

Actual Outcomes in 2004:

1. A text book on gas cooling technologies was completed. In the 4th quarter, the R&D review team reviewed the draft final, and voted to make the textbook available free in electronic form. The final version will be made available for free download at the public side of the Cooling Solutions website early in 2005.
2. A TRNSYS (Transient Energy System Simulation Tool) desiccant model and white paper was completed.

3. Product Development and Field Testing.
   - DryKor TAC-10 Thermal Air Conditioner Field Demonstration:
     The TAC-10 was installed but was inoperative through most of the 3rd quarter due to support equipment problems. Repairs are being made, and once the system is fully operational its efficiency will be determined. At this time, the equipment has proven to be reliable and capable of controlling building humidity. Early indications are that the TAC can provide adequate sensible cooling with 10 tons of capacity as advertised by DryKor. An advantage of the liquid desiccant is that the lithium chloride kills bacteria, viruses, and other microbial growth on contact so the returned process air is biologically uncontaminated. The primary concern during this testing period is the possibility that the lithium chloride can carry over into the ductwork or into the building.
   - Walgreen's ColdPower/Semco:
     The internal combustion engine was installed. The 4th quarter focus was on establishing data communication links, installation of the desiccant unit, and validation of the communication protocol.

Project Status:
The project is expected to be completed by June 2005.

Demonstration of a New, High-Efficiency Air-Conditioning System

Contract #: 500-02-012
Contractor: CoolSmart LLC
Subcontractors: C&B Consulting Engineers : Markusen Consulting
Contract Amount: $99,000
Match Amount: $105,950
Contractor Project Manager: Bill Kopko (703) 323-9578
Commission Contract Manager: Brad Meister (916) 653-1594
Status: Active

Project Description:
The purpose of this project is to demonstrate a new air-conditioning system in a Southern California retail facility. The system, designed and patented by CoolSmart, LLC, shows promise for greatly reducing energy use and peak electric demand for cooling commercial buildings. The demonstration should also show if the system satisfies comfort and operating requirements for the building and identify remaining design issues for future work. CoolSmart's system differs from conventional air conditioning in that it separates dehumidification and sensible cooling, allowing for most of the cooling to be done at a higher evaporating temperature. The CoolSmart system uses a ceiling plenum for air distribution at a very low static pressure.

This project supports the PIER Program objective of:
- Improving the energy cost/value of California's electricity by demonstrating a new, energy-efficient air-conditioning system that is suitable for use in commercial buildings.

Proposed Outcome:
1. Reduce HVAC system energy use by 30 to 60 percent, with total installed cost equal or lower than comparable systems.

Project Status:
The project was approved in late 2002 and began in early 2003. The project's initial demonstration partner dropped out after completion of an initial design. A demonstration is planned with a new partner but the project has now been delayed approximately eighteen months. The contract has already been extended once but will be extended again in Q1 2005 if the demonstration goes ahead as currently planned.

Energy Efficient Low Income Housing Program

Contract #: 400-00-036
Contractor: ADM Associates, Inc.
Subcontractors: Texas A&M University, Energy Systems Laboratory : Florida Solar Energy Center : University of Nebraska : Robert Penny Enterprises
Contract Amount: $997,850
Contractor Project Manager: Taghi Alereza (916) 363-8383
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Program Description:
The purpose of this program is to develop information, strategies, and technologies that contribute to reducing energy use and its related expense in low-income households. There are seven energy efficiency projects in the program and they apply to both new and existing housing for low-income households. Two national housing groups, Habitat for Humanity (or HfH, www.habitat.org) and Mercy Housing (or MH, www.mercyhousing.org) and two manufactured housing builders, Skyline Homes (www.skylinehomes.com) and Fleetwood Homes (www.fleetwoodhomes.com) are participating to help ensure that the program results are used in this housing market. This program includes 38 test houses and 106 control houses for monitoring results. This program is unique because it specifically addresses energy needs of low-income households. Low-income households often incur relatively higher energy costs than higher income groups because of cost barriers commonly associated with energy efficiency measures. This research program focuses on low-cost options to reduce monthly energy costs and improve the quality of life by improving comfort levels in homes.

This programmatic contract supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by reducing cooling energy use in new and existing buildings, integrating energy-efficient strategies and products with other building elements, and searching for the highest value strategies and technologies for retrofit.
- Improving the environment, public health and safety by developing ventilation and construction techniques that mitigate moisture and indoor air quality (IAQ) problems.
- Providing greater choices for California consumers by increasing consumer load management choices.

Description of Element 1 – Program Administration:
The administration element coordinates and integrates the technical program elements for the Energy Efficient Low-Income Housing program. Element projects include a kick-off meeting, program meetings, annual technical briefings, monthly progress reports, a final report and a final program meeting. With several organizations participating in this program, the Program Director is responsible for managing the proposed program to achieve the program and project goals within allocated budget and schedule.

Proposed Outcomes for Element 1:

1. Produce all deliverables on time and within budget.
2. Establish public and team web sites to communicate project results and manage project activities.
3. Conduct outreach efforts to facilitate adoption in the marketplace.

Program Status of Element 1:

In addition to completing program administrative activities such as conducting program meetings and completing monthly progress reports, ADM has established a public website for program support and information distribution at:

⇒ www.adm-energy.com/pier

Description of Element 2 – Energy Efficient Low-Income Housing:

The technical element of this work is to improve the energy efficiency of housing often occupied by low-income households. Such housing includes homes built by groups such as Habitat for Humanity (HfH), Mercy Housing (MH) and manufactured housing builders. The relatively higher cost of energy efficient technologies has often precluded them from being installed in low-income housing (e.g., efficient air conditioning, heat pump water heaters, etc.). In houses built by HfH or MH, volunteer workers including the eventual homeowners provide most of the construction labor. This means that implementing more labor-intensive efficiency techniques in the home is a better option for these homes than in houses built for the general population, where high efficiency equipment may be added to the total home cost in the form of an upgrade.

Element 2 includes the following seven projects:

2.1) Attic Ventilation.
2.2) Attic Heat for Water Heating.
2.3) Ducts in Conditioned Space.
2.4) Envelope and IAQ Interactions.
2.5) Simplified HVAC Controls.
2.6) Evaporative Coolers and Whole House Fan Integration.
2.7) Energy Efficiency through Community Design.

The Attic Ventilation project compares the performance of two different methods for decreasing attic heat loads in HfH and manufactured housing to evaluate the relative effectiveness and cost of these methods in reducing space conditioning loads. The objective of the Attic Heat for Water Heating project is to design and evaluate a system for recovering heat from attics in HfH and manufactured houses and use the system for domestic water heating. The Ducts in Conditioned Space project goal is to reduce or eliminate energy losses from air conditioning ducts that are usually placed in unconditioned spaces. The objective of the Envelope and Indoor Air Quality (IAQ) Interactions project is to evaluate the energy efficiency measures that can be implemented in housing for low-income households without exceeding IAQ standards. The Simplified HVAC Controls project objective is to evaluate options for easier-to-use controls, such as occupancy thermostats, for space conditioning systems and understanding how these measures may affect low-income housing energy use. The goal of the Evaporative Coolers and Whole House Fan Integration project is to determine if integrating a whole house fan with a standard or an evaporative cooling system provides an economically viable, efficient alternative for comfort cooling needs in new houses for low-income households. The Energy Efficiency through Community Design project is determining how best to incorporate narrow streets and shade trees into the designs of low-income single-family housing developments to reduce ambient temperature.

Proposed Outcomes for Element 2:

1. Quantified comparison of selected attic ventilation methods will be used for reducing energy costs related to house conditioning for HfH and manufactured homes. This comparison takes into account implementation costs, which will include all equipment, material and labor costs at market rates.
2. A viable attic heat recovery system design for pre-heating domestic hot water, based on a comparison of several systems designed, developed and implemented in low-income houses. Quantitative analysis of each design using field monitoring data will determine final system recommendation.
3. An improvement in duct design in conditioned space for low-income houses or a validation of current methods by implementing and testing different designs of ducts in conditioned space. An optimal duct design will be determined from two rounds of testing with intermediate analysis and system concept refinement.
4. Quantitative findings of IAQ improvements resulting from implementing various envelope construction methods and ventilation strategies by measuring carbon dioxide, carbon monoxide, and in some cases mold concentrations in low-income houses.
5. Recommendations on improving low-income housing energy efficiency through HVAC controls based on field study of programmable thermostat versus occupancy thermostat usage and the corresponding energy impacts.
6. A viable residential design that combines either the whole-house fan plus evaporative cooling/standard air-conditioning or involves whole-house fan alone, and incorporates a simplified, user-friendly control system, based on the quantitative data analysis of temperatures and IAQ plus system effectiveness.
7. A strategy incorporating narrow streets and shade trees into low-income housing developments along with algorithms for estimating the potential energy savings, based on data collected from various low-income housing developments in varying degrees of compliance with the suggested design of streets and trees.

Actual Outcomes for Element 2:

1. Project 2.1, Attic Ventilation:
   ADM monitored the effect of installing radiant barrier in two retrofit house projects by HfH and in two new manufactured houses built by Skyline Homes. The project also monitored automatic low-cost, low water volume roof spray systems designed to reduce attic heat build-up in two different house projects by HfH. Both the radiant barrier and roof spray systems were effective at reducing attic heat buildup.
2. Project 2.2, Attic Heat for Water Heating:
   ADM designed and installed attic water pre-heating systems in several HfH and MH homes throughout the State. These low-cost systems hold about the same volume as a residential hot water storage tank and are integrated into the home's standard hot water system.
3. Project 2.3, Ducts in Conditioned Space:
   ADM constructed interior duct systems in four different houses, where a sealed dropped plenum above hallway ceilings is used to deliver conditioned air into living spaces. Duct leakage on these homes was less than 2%.
4. Project 2.4, Envelope and IAQ Interactions:
   The researchers conducted IAQ monitoring of houses with several of the program technologies.
5. Project 2.5, Simplified HVAC Controls:
   ADM developed a prototype occupancy thermostat with simple one-hour heating/ cooling override buttons. Twelve of these 'Simple Thermostats' were installed in demonstration houses.

6. Project 2.6, Evaporative Coolers and Whole House Fan Integration:
   The researchers demonstrated several low-cost options for improving residential HVAC energy efficiency by integrating evaporative coolers, whole house fans, and/or economizers with conventional air conditioners. Adding evaporative coolers to conventional HVAC systems appears to be a cost-effective way to save cooling energy in California's hot Central Valley.
7. Project 2.7, Energy Efficiency through Community Design:
   ADM collected ambient temperature data from five manufactured home and trailer communities in Sacramento with tree canopy coverage ranging from 10% to 90%. They are using the results to develop a database that can model these communities with the goal of designing neighborhoods with reduced space conditioning load by lowering the ambient outdoor local temperature.

Project Status:
All field work was completed as of December 2004. Project and program Final Reports will be available in the first half of 2005.

Field Study of the Impacts of Underfloor Air Distribution

Contract #: 500-01-015
Contractor: California Department of General Services
Subcontractors: University of California - Center for the Built Environment
Contract Amount: $97,000
Contractor Project Manager: Teresa Kaneko (916) 323-9872
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The California Energy Commission and the Department of General Services (DGS), through an Interagency Agreement, will jointly fund a field study of the impacts of underfloor air distribution in new office buildings. The Capitol Area East End Complex, a recently completed state office building construction project, will be the site for this field study. The Center for the Built Environment, a research organization within the University of California, Berkeley will conduct this field study under contract to DGS.

Underfloor Air Distribution (UFAD) systems use the open space (underfloor plenum) between the structural concrete slab and the underside of a raised floor system to deliver conditioned air directly into the occupied zone of the building. UFAD systems are typically applied in office and other commercial buildings. UFAD systems represent a highly integrated system since the supply plenum is used for the dual purposes of wiring distribution and air delivery, and diffuser layouts are closely coordinated with occupant layouts, allowing occupant interaction with the system in a way not typically possible with conventional systems.

Rarely has an innovative system concept offered UFAD's combined potential of energy savings, and health, comfort and productivity benefits. Timely research is critical to support the successful development of this important new direction in HVAC system practices and integrated building solutions. It is in the public interest to objectively evaluate the energy performance and occupant benefits of UFAD systems that are beginning to penetrate California building markets. It is important to document both the energy and non-energy benefits of this technology. This information will be useful to both public and private organizations responsible for funding commercial building construction.

This project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity to building owners and occupants by verifying the energy savings, and health, comfort and productivity benefits of innovative building energy systems.

Proposed outcome:

1. This study will provide critical guidance to California for future efforts in achieving energy-efficient, sustainable, and healthy buildings. Because this will be the first state building to use underfloor air distribution, this project could have a significant and potentially long-term influence on future design, operation, and maintenance standards for state office buildings.

Project Status:
Field studies and occupant surveys have been completed to document the baseline building conditions where the State employees used to work. The construction of Block 225 is completed, the building has been commissioned, and California Department of Education employees are now working in the building. Initial field studies and occupant surveys have indicated that the UFAD system is not operating as designed, causing some unnecessary comfort problems and energy waste. An extended commissioning process is underway to bring the UFAD system into conformance with the design intent. Research monitoring will be continued, to capture the changes in energy use and occupant satisfaction after the system is re-commissioned. This project is expected to be complete in December 2005.

Hot Dry Optimized AC

Contract #: 500-03-002
Contractor: Southern California Edison
Subcontractors: Proctor Engineering Group
Contract Amount: $1,985,897
Match Amount: $804,223
Contractor Project Manager: Gregg Ander (626) 633-7160
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
This project will design and test 5-ton packaged and 3.5-ton split system air conditioning equipment that has an optimized life-cycle cost for hot-dry conditions as found in the southwestern US and elsewhere. Manufacturers are being enlisted to build prototypes and the major California utilities will be evaluating the products for incentive programs. The prototypes will be field tested to ensure that they perform well in actual conditions.

This project supports the PIER Program objectives of:

- Improving the value of California's electricity by producing cooling equipment that produces comfortable conditions while using less energy.
- Strengthening California's economy by creating new products.
- Improving the reliability of California's electrical supply by reducing peak electrical demand related to small air conditioning equipment.

Proposed Outcomes:

1. Design air conditioning equipment that can provide approximately 15% energy and demand benefit in hot-dry conditions compared with Seasonal Energy Efficiency Rating (SEER) 13.
2. Large scale distribution of the equipment from major manufacturers.

Project Status:
Project began February 17, 2004. A high-quality regional manufacturer has joined the project team. A proof-of-concept design is complete and being presented to manufacturers for comment. The final proof-of-concept will be constructed for performance evaluation.

Investigation of Mold-Resistant Building Assemblies and Construction Practices for California Homes

Contract #: 500-03-013
Contractor: Gas Technology Institute
Subcontractors: University of Illinois - Energy Resources Center
Contract Amount: $997,053
Match Amount: $205,750
Contractor Project Manager: Neil Leslie (847) 768-0926
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
This project is a detailed investigation of residential building construction practices and innovative building assemblies that are resistant to mold formation and growth.

This project supports the PIER Program objectives of:

- Facilitating the construction and operation of buildings that are energy efficient and healthy by demonstrating energy-efficient and mold-resistant building assemblies.
- Improving building affordability and value by addressing the costs associated with mold incidences in residential buildings.

Proposed Outcomes:

1. Provide technical data on mold-resistant building systems for use in revisions to California Title 24 residential building energy standards.
2. Publish guidelines on building materials and construction practices that prevent or mitigate moisture migration from external or internal sources.
3. Provide a relational database linking mold incidences, construction details, and climatic conditions.
4. Identify, evaluate, and recommend cost-effective residential construction practices and building assemblies that resist mold growth in the presence of moisture.

Project Status:
The project started in December 2003. Efforts in Q1 2004 focused on characterizing the nature of residential mold problems in California. The researchers completed a literature search and analyzed insurance water claims data with cooperation from the California Department of Insurance. Later in the year, the researchers started testing various building assemblies in the laboratory, focusing on water management characteristics of window assemblies, stucco walls, and concrete slabs. Demonstration projects with California production builders are planned for 2005.

Lighting Research Program

Contract #: 500-01-041
Contractor: Architectural Energy Corporation
Subcontractors: Lawrence Berkeley National Laboratory : Loisos/Ubbelohde : John Kesslering, Consultant : New Buildings Institute, Inc. : Bevilacqua-Knight, Inc.
Contract Amount: $5,211,190
Match Amount: $2,843,170
Contractor Project Manager: Judie Porter (303) 444-4149
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Active

Program Description:
The purpose of the Lighting Research Program (LRP) is to conduct a systematic lighting research program that creates new lighting technology and products that can save energy, reduce peak demand, and reduce pollution for the citizens of California. Over 23 percent of the electricity used in California is for lighting. This Program encompasses both residential and commercial sectors, as well as outdoor lighting associated with buildings. The Program integrates the research activities with lighting equipment manufacturers, providing a great asset for introducing the products to the market.

This programmatic contract supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by providing reducing cost with energy-saving lighting equipment.
- Improving the reliability/quality of California's electricity by reducing peak demand and improving load factor, leading to reduced infrastructure costs and system reliability risks.
- Improving the State's economy by developing new lighting products manufactured in California.

Description of Element 1 – Program Administration:
The purpose of this element is to provide program administration for all technical elements and provide overall coordination and integration of all the subcontractors and work tasks. The prime contractor manages the technical work in addition to handling all administrative activities (e.g., contracts, billing, reporting, tracking, etc.) to ensure that all tasks are completed within the allocated budget and schedule.

Proposed Outcomes for Element 1:

1. Ensure that all tasks are completed on time and within budget.
2. Create public and team web sites to communicate project results and manage project activities.

Program Status of Element 1:

1. In addition to completing extensive administrative tasks (manage subcontracts, issue bills, and produce reports) Architectural Energy Corporation (AEC) has conducted several Program Advisory Committee (PAC) meetings.
2. An extensive project web site is available at:
   ⇒ www.archenergy.com/lrp/default.htm

Description of Element 2 – Advanced Lighting Technologies:
The purpose of this element is to reduce energy usage by researching and developing a series of high performance energy efficient LED based alternatives to incandescent applications.

Proposed Outcomes for Element 2:
Develop and research the market availability of the following products:

1. LED luminaries for exterior, porch, and perimeter lighting.
2. An office task-lamp using a 50 lumen/watt, 1000 lumen LED source.
3. A low-profile LED fixture for applications such as under shelves/cabinets.

Program Status of Element 2:

- The California Lighting Technology Center developed a series of hybrid LED/CFL fixtures for exterior applications. Manufacturers Shaper Lighting and the WattStopper have incorporated the concepts into commercially available products.
- Lawrence Berkeley National Laboratory (LBNL) developed a working prototype of an LED task lamp that exceeds the performance of a compact fluorescent lamp. Luxo has started marketing the concept by integrating it into their Arketto Lamp.
- The Lighting Research Center developed a prototype low-profile LED fixture and demonstrated it in an elevator application.

Description of Element 3 – Demand Responsive Systems:
The purpose of this element is to develop and produce lighting controls and systems that respond to daylighting and demand-limiting signals.

Proposed Outcomes for Element 3:

1. Develop a retrofit fluorescent dimming system.
2. Develop an instant-start load-shed ballast for fluorescent lighting.
3. Develop a classroom photocell and control system for fluorescent lighting.

Program Status of Element 3:

- LBNL with Vistron have developed a proof-of-concept retrofit fluorescent system, using wireless and powerline carrier communications technologies. The system was tested by PG&E and manufacturing partners have been contacted to produce the various components of the system.
- The Lighting Research Center developed a load-shed ballast that is designed to replace existing instant start ballasts in fluorescent lighting fixtures. When a signal is received via powerline carrier communications, it dims the fluorescent light fixture, reducing the lighting power. Osram Sylvania is producing a first batch of load-shed ballasts, which will be demonstrated on UC/CSU campuses.
- Produced electric lighting/daylighting simulations for six common classroom configurations and created a performance specification for the new self-commissioning photocell. The WattStopper developed and demonstrated a prototype product meeting the performance specification, and demonstrated it in a Southern California Edison modular classroom. A next-generation design is underway.

Description of Element 4 – Advanced Lighting Systems and Luminaires:
The purpose of this element is to develop and produce integrated lighting systems, including luminaires and controls (on/off and dimming), that are easily designed, installed, and commissioned.

Proposed Outcomes for Element 4:
Develop/produce/test the following:

1. An institutional bathroom fixture using an LED nightlight and integrated controls for new and retrofit applications.
2. EnergyStar-rated residential table lamps using pin-based compact fluorescent lamps (CFL).
3. A retrofit CFL downlight lighting system for residential and commercial applications.
4. A dimmable CFL floor lamp with uplight and downlight components and integrated dimming/occupancy/network controls for commercial applications.
5. An integrated classroom lighting system using highly reflective paint and dimming/occupancy controls.

Program Status of Element 4:

- Completed a successful demonstration of a retrofit bathroom LED nightlight developed by the WattStopper at 400 rooms in a Sacramento hotel, with average energy savings of 46%. Also developed a bathroom "smart fixture" in collaboration with Speclight.
- In collaboration with EPA's EnergyStar program, ran a design competition which stimulated the development of four designs for EnergyStar pin-based CFL table lamps. Two are currently in the market and two more will be in production soon.
- Working with Lithonia, the California Lighting Technology Center (CLTC) developed two retrofit systems: one commercial system is currently on the market and a second system for residential is under development.
- The CLTC and Finelite worked together to develop a floor-standing fixture that separately adjusts ambient and task lighting. LBNL developed building-level control strategies.
- Finelite developed and field tested an Integrated Classroom Lighting System (ICLS). The ICLS was demonstrated in nineteen California classrooms, with approximately 50% energy savings.

Description of Element 5 – Lighting Performance Metrics, Codes and Standards:
The purpose of this element is to identify and develop solutions to codes/standards and performance metrics issues that inhibits adoption of high-efficiency or energy-savings lighting technologies.

Proposed Outcomes for Element 5:

1. Gain acceptance by code officials and facility owners of a bi-level stairway/ hallway lighting fixture that allows reduce lighting levels during unoccupied periods.
2. Test high-intensity discharge (HID) electronic ballasts to: 1) Determine the potential for control strategies to further improve these systems' energy efficiency, and 2) Provide recommendations for incorporating these technologies into current state codes and regulations.
3. Develop a low-glare outdoor retrofit luminaire that would improve the efficiencies of existing luminaires by up to 30 percent.
4. Develop and gain industry acceptance of an enhanced Digital Addressable Lighting Interface (DALI) control standard that offers a standard command structure for control devices.

Program Status of Element 5:

- Four demonstration sites were installed with LaMar fixtures and monitored. LBNL analyzed the results. Workshops were conducted with International Facility Management

Association (IFMA) to educate end-users. A white paper was written on the codes and standards issues.

- LBNL performed the measurements to characterize the performance on more than 90 HID lamp-ballast systems. Reports detailing the results for both low and high wattage systems were developed.
- LBNL analyzed relevant data on outdoor lighting and used computer simulations to develop a prototype design for a cost competitive outdoor luminaire with higher efficiency, higher optical performance, and better light quality than existing products. Gardco developed a prototype unit and is working toward commercialization.
- PIER brought together a National Electrical Manufacturers Association (NEMA) facilitated working group to develop an enhanced Digital Addressable Lighting Interface (DALI) standard. The process included roundtables with designer and end-user groups, two demonstrations at The WattStopper's facilities, and a proposed standard that will be adopted in late 2005.

Description of Element 6 – Market Connection:
The purpose of this element is to provide an innovative, centralized program-wide approach to improve the market focus of this Program's activities and thereby to increase the ultimate commercial viability of the Program's technology products. It provides all the Program's R&D projects with product assessment and commercialization recommendations from key lighting market experts, and assists the developers of the most market-ready products in the transition from R&D to production and market entry. This element will also provide a consistent set of product-descriptive materials for use in industry reference and public education by the Commission, individual product developers, and other market actors.

Proposed Outcomes for Element 6:

1. Develop a program-wide market connection system, including a virtual review panel, commercialization alliances, and early product commercialization support.
2. Develop technology and product design tools targeting specific to aid decision makers and system designers.
3. Perform a lighting R&D/codes scoping study to evaluate all Program lighting research efforts for the purpose of identifying the most code-ready research outcomes and identify those that may require additional R&D before they can enter the code process.

Program Status of Element 6:

- Bevilacqua-Knight, Inc. (BKi) provided guidance to Lighting Research Program (LRP) project teams regarding economic product evaluations, business case development, and evaluating incentive and avoided cost issues.
- AEC developed three case studies and SPOT software, which assists users to establish the correct photosensor placement relative to the proposed daylighting and electric lighting design, and to analyze overall design performance (www.archenergy.com/SPOT/index.html).
- Heschong Mahone Group (HMG) evaluated all the LRP efforts, and mapped a path from each into the codes and standards arena. They identified the most code-ready technologies and recommended steps to adoption, and identified those projects that may require additional R&D. HMG also provided recommendations on future lighting R&D.

Modeling for Under Floor Air Distribution (UFAD)

Contract #: 500-01-035
Contractor: Regents - Berkeley
Subcontractors: University of San Diego
Contract Amount: $610,000
Match Amount: $310,000
Contractor Project Manager: Fred Bauman (510) 642-7848
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Project Description:
The goal of this project is to develop Under Floor Air Distribution (UFAD) system simulation software that can be used by design practitioners to calculate the energy performance of UFAD systems and to compare the performance of UFAD systems with that of conventional systems. The availability of such a tool will help UFAD technology achieve its full potential by enabling the design of UFAD systems that are energy efficient, intelligently operated, and effective in their performance.

This project supports the PIER Program objectives of:

- Improving the Energy Cost/Value of California's Electricity by fostering the implementation of energy efficient UFAD systems.
- Improving the Environmental and Public Health Costs by insuring that UFAD systems are properly designed to maximize their indoor environmental health and occupant comfort benefits.

Proposed Outcomes:

1. Decrease cooling energy and fan energy end-use consumption in commercial buildings by fostering adoption of UFAD technology in 15-40 percent of the building stock.
2. Improve the effectiveness of building design and construction practices by providing a validated tool that optimizes the energy and cost effectiveness of UFAD systems and provides the basis for further design tool development.
3. Improve the health and safety of building occupants by establishment of a database of test information that could be used to analyze thermal comfort of UFAD systems and assist with future studies of ventilation effectiveness.
4. Increase customer choices for efficient operation of buildings by providing standardized design and analysis tool and technical knowledge that would reduce the risk to practitioners and owners when choosing to implement UFAD technology.
5. Encourage the rapid incorporation of research findings into UFAD products by virtue of working closely with UFAD industry leader York International, a partner on this project, and other major HVAC manufacturers who are members of CBE.

Project Status:
Work continues in four major areas: 1) full-scale room air stratification (RAS) testing and model development, 2) salt-water tank room RAS testing and model development, 3) underfloor plenum testing and model development, and 4) integrating these models into U.S. DOE's building thermal response simulation tool, EnergyPlus. This project is expected to be complete in December 2005.

National Lighting Product Information Program and Daylight

Contract #: 500-02-010
Contractor: Rensselaer Polytechnic Institute
Contract Amount: $450,000
Contractor Project Manager: Russ Leslie (518) 687-7100
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Active

Project Description:
The purpose of this project is to participate in The Lighting Research Center's (LRC) two collaborative research programs the National Lighting Product Information Program (NLPIP) and the Daylight Dividend Program (DDP) from 2003 through 2005.

The purpose of the ongoing NLPIP program is to continuously research technical issues, perform testing, and provide objective manufacturer-specific information on lighting products and systems. Materials, available in hard copy and on-line, include testing reports and educational information concerning a number of lighting and related technologies including T-5 fluorescent lamps. The purpose of the DDP is to build the market demand for daylight as a means of improving indoor environmental quality, overcome the technological barriers to effectively reap the energy savings of daylight, and to inform and assist state and regional market transformation and resource acquisition program implementation efforts.

This project supports the PIER Program objective of:

- Improving the energy cost/value to California consumers by offering lower cost to lighting-system owners.

Proposed Outcomes:

1. Commission funding will expand NLPIP research efforts and direct the results, along with all other NLPIP results, toward lighting decision-makers in California.
2. The DDP research will focus on two areas that have been identified as needing significant improvements to ensure that effective daylighting will become common in commercial buildings.
   - The first area involves clarifying the benefits of daylight.
   - The second area is the need to advance the technological components – photosensors, dimming systems, ballasts – that are required to achieve the greatest energy benefits of daylighting without compromising the comfort and satisfaction of building occupants.

Project Status:
NLPIP has released several new resources, available at:
⇒ www.lrc.rpi.edu/programs/NLPIP/index.asp
The DDP project web site is available, with several interim reports, at:
⇒ www.lrc.rpi.edu/programs/daylightDividends/index.asp

NightBreeze Products

Contract #: 500-02-026
Contractor: Davis Energy Group, Inc.
Contract Amount: $279,083
Match Amount: $80,272
Contractor Project Manager: Mark Berman (530) 753-1100
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
The purpose of this project is to adapt the NightBreeze technology, which is for residential ventilation cooling, to the production and custom home markets. This will be accomplished by integrating existing NightBreeze technology with another widely-marketed ventilation system, a variable speed gas furnace, and by designing a fan coil specifically for the existing hydronic NightBreeze technology. The project will also develop an integrated multi-zone controller to improve residential efficiency, especially in two-story houses.

This project supports the PIER Program objectives of:

- Improving the energy value of California's electricity by significantly increasing the efficiency of residential cooling.
- Improving indoor residential environments by automatically ventilating homes with filtered outside air, thus improving their indoor air quality.

Proposed Outcomes:

1. Develop a viable energy-efficient gas furnace-based residential ventilation cooling system designed for new construction 'starter' homes in the production builder market. This product will improve on the automatic control capability of an existing simple ventilation system (residential economizer) and undergo laboratory testing.
2. Develop a viable gas furnace-based residential ventilation cooling system that allows for even better efficiency in residential ventilation cooling. This product is for new construction in the custom home and luxury home production builder markets. It will integrate an existing variable-speed gas furnace with the residential economizer system and undergo field testing.
3. Develop the integrated capability to control two-speed furnaces, multiple zones, and both air conditioners and heat pumps with or without electronically-commutated motors (ECMs) for residential applications.
4. Develop the production capability for the current hydronic NightBreeze air handler by completing airflow testing, creating a production air handler design and drawings, and then building ten production NightBreeze systems.
5. Remove market barriers and promote efficient ventilation cooling technology in the State by obtaining safety test evaluations and developing technology transfer opportunities.

Project Status:
The project is nearly complete, with most technical tasks completed and final reports in preparation.

Power Supplies Efficiency Improvement

Contract #: 500-01-025 **Work Authorization #:** E2I-WA-008
Contractor: Electricity Innovation Institute
Subcontractors: Ecos consulting
Project Amount: $288,541
Match Amount: $288,541
Contractor Project Manager: Rick Counihan (650) 855-2170
Commission Contract Manager: Brad Meister (916) 653-1594
Status: Active

Project Description:
The purpose of this project is to assess the state of current power supply technology, understand the market dynamics, work with industry and users to develop and apply high-efficiency power supplies, and develop an action plan to transform the power supply market to improve efficiency in all operating modes.

This project supports to the PIER program objectives of:

- Improving the energy cost/value of California's electricity by reducing cost with energy-saving lighting equipment.
- Improving the reliability/quality of California's electricity by reducing peak demand and improving load factor, leading to reduced infrastructure costs and system reliability risks.
- Improving the State's economy by developing new lighting products manufactured in California.

Proposed Outcomes:

1. Confirm the efficiencies of 75 existing power supplies through application of a new universally recognized test protocol.
2. Characterize current power supply technology and markets, and assess energy savings from adopting higher-efficiency power supplies in California.
3. Increase, by a minimum of five, the number of emerging, high-efficiency power supplies that are more efficient than existing power supplies, utilizing a design competition conducted in concert with industry stakeholders.
4. Develop an action plan to ensure that knowledge and results gained are available to key decision makers.

Project Status:
The project Final Report will be available in H1 2005.

1. The research team has tested over 170 power supplies and developed test protocols for internal and external power supplies. Results are posted at:
   ⇒ www.efficientpowersupplies.org
2. The researchers developed a power supply efficiency technical primer.
3. A design competition to stimulate high-efficiency power supplies was announced at the Applied Power Electronics Conference (APEC) on February 23, 2004. The Design Competition closed on December 17, 2004. Winners will be announced at the March 2005 APEC.
4. Project test results helped influence Intel to increase recommended power supply efficiencies by about 30% at 20% and 50% load levels.

Profitability, Quality and Risk Reduction through Energy Efficiency

Contract #: 400-00-037
Contractor: Building Industry Institute
Subcontractors: ConSol Consulting
Contract Amount: $996,020
Match Amount: $1,450,000
Contractor Project Manager: Robert Hammon (916) 443-7933
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Active

Program Description:
The purpose of this program is to develop new profit incentives for California homebuilders that will encourage energy-efficient construction. The profit incentives will be generated through reduced warranty costs, increased sales through improved mortgage products, and improved builder and consumer value of energy efficiency through its association with quality and comfort. This contract will also provide builders and their designers with improved analytical tools that will better demonstrate heating, ventilating and air conditioning (HVAC) sizing differences and their associated cost savings, due to quality installations.

This programmatic contract is targeted to the new housing market in California and includes production homebuilders on the program team. These homebuilders will provide information at key times throughout the research and will also review the products for practicality, cost and marketability.

This programmatic contract supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by developing efficient technologies and strategies to increase building value and measure benefits.
- Strengthening the California economy and providing greater consumer choice by working directly with production homebuilders to identify construction practices that simultaneously improve energy efficiency and increase profitability.

Description of Element 1 – Program Administration:
This administrative element encompasses overall coordination and integration of the four technical projects of this research program.

Proposed Outcomes for Element 1:

1. Research deliverables on time and within budget.
2. Public and team websites that communicate project results and manage project activities.
3. Presentations, articles and research papers conveying the results of the research, provided to the buildings community.

Program Status of Element 1:
The administrative infrastructure for the research program is in place. Much of the effort has focused on re-scoping the project to respond to developments outlined below.

Description of Element 2 – Technical Research:
This technical element is composed of the following four large, inter-related research projects:

1. Improved Energy Efficiency, Comfort, and Quality Construction through Reduced Warranty Calls – This project provides a unique opportunity to have builders, a warranty provider, and research organizations work together to make increased energy efficiency

in new California homes cost-effective. Production builders' consumer calls will be analyzed to segregate calls into groups, such as structural, HVAC, and moisture. The resulting groups of calls will be correlated with the costs of the warranty calls and possible energy-related improvements in construction techniques and or improvements in energy-related features in the homes. Improved construction practices will be identified and put into a form that is useful to the builder and subcontractors.

2. Value of Quality, Comfort and Energy Efficiency in New Homes – This project will clearly establish the level of consumer interest in energy efficiency, by itself, and when coupled with the additional benefits of quality and comfort. Home Energy Rating Systems will be developed to help consumers compare energy efficiency, quality, and comfort of new homes.
3. Increase Energy Efficiency through Improved Mortgage Products – If significant correlations of home quality, comfort, and energy efficiency problems to home foreclosures are found, the research team will develop a mortgage product that reduces the risk of foreclosures. This project will use the improved home construction practices developed in Project 1, and the home rating system developed in Project 2, to provide a new quality construction mortgage that is relevant to California homes.
4. Improved HVAC Design Mechanisms – This project will develop calculation methods and a design guide for improved HVAC system design.

Proposed Outcomes for Element 2:

1. Improved construction protocols will be available for wide distribution. These protocols will not only solve the construction defects but also improve home quality, comfort and energy efficiency.
2. A new home rating system will be developed and will be useful for builders as a quality assurance test and for new-home buyers to determine the relative quality, comfort, and energy efficiency of new homes.
3. The national Secondary Lender participating in this program is likely to implement the new mortgage guidelines that use the quality, comfort, and energy efficiency rating to reduce risk.
4. Improved calculation methods and a design guide for improving Air Conditioning Contractors of America (ACCA) HVAC system design software.
5. Tools for builders, HVAC designers and subcontractors to optimize HVAC system design, to reduce energy consumption, and save materials and equipment costs.

Program Status of Element 2:

1. Improved Energy Efficiency, Comfort, and Quality Construction through Reduced Warranty Calls – The research team worked with several builders and a home warranty provider to find data sources for building a database of warranty callback problems. Unfortunately, they discovered that the data being captured by the industry today is not rich enough to support the originally envisioned analyses. Structured interviews with leading California homebuilders indicated that HVAC problems were a common source of callbacks, but did not establish that other typical sources of construction defects and callbacks were strongly linked to energy efficiency. Since a later project is addressing HVAC concerns, the remainder of this project was terminated.
2. Value of Quality, Comfort and Energy Efficiency in New Homes – This project was on hold pending results from the qualitative survey methodology outlined above. This project intended to propose an improved quality, comfort, and energy efficiency rating system informed by the findings of Project 1 above. Since the researchers were unable to establish a broad link between callback-related defects and energy efficiency, this project was also cancelled.

3. Increase Energy Efficiency through Improved Mortgage Products – Investigation of mortgage foreclosure data showed that the data currently collected is not adequate to establish a statistically significant link between quality, comfort, and energy efficiency problems and home foreclosures. Therefore, this project ended in the first year of the program.
4. Improved HVAC Design Mechanisms – A preliminary assessment of calculations and design practices widely used for HVAC sizing is largely complete. This assessment and results of a Computational Fluid Dynamics (CFD) model used to establish optimal register locations will feed into a design guide for residential HVAC systems.

Project Status:
The project is nearly complete. The final draft of the Residential HVAC Design Guide is underway, and the outline of the Final Report is complete. This contract was amended in January 2005 to reduce the scope and budget to account for the cancelled research activities. This project is expected to be complete in March 2005.

Residential Retrofit Commissioning

Contract #: 500-02-011
Contractor: Bevilacqua-Knight, Inc.
Contract Amount: $414,717
Contractor Project Manager: Robert Knight (510) 444-8707
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Project Description:
Complex systems in modern houses produce major opportunities for energy waste through leaking ducts, faulty equipment, and problems with the building envelope. Few contractors fully understand how systems within houses interact or how to diagnose and repair problems beyond a narrow specialty. The purpose of this project is to merge scientifically validated diagnostic and repair techniques for residential thermal comfort systems with the business practices of existing contractors. It is using a group of selected contractors to appraise which scientifically validated methods can be used in everyday contracting. The methods will be documented and training materials developed. The net benefits will be validated by before and after energy use monitoring and occupant surveys.

This project supports the PIER Program objectives of:

- Improving electricity reliability/sufficiency by making existing residences more energy efficient.
- Strengthening the California economy by improving the productivity of California residential contractors.
- Improving public health and safety by providing more comfortable and healthful indoor environments.

Proposed Outcome:

1. Build on previous PIER-funded residential commissioning research and develop it into a practical service. The project will help augment the small number of California residential commissioning contractors, demonstrate the value of this service, and provide the necessary knowledge for replicating it on a larger scale.

Project Status:
A survey of performance contractors has been made, and development and documentation of practical methods is under way. Business model assessment is also on-going. Energy benefits of commissioning are being determined. Many of the contractors trained in this project are working in a synergistic project sponsored by the California Public Utilities Commission.

Synergistic Water Heating and Distribution Technologies Program

Contract #: 400-00-038
Contractor: Davis Energy Group, Inc.
Subcontractors: Maytag Corporation : Iris Power Engineering, Inc. : Oak Ridge National Laboratory : TIAX LLC : Amaro Construction
Contract Amount: $767,038
Match Amount: $473,343
Contractor Project Manager: Mark Berman (530) 753-1100
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Active

Program Description:
The purpose of the Synergistic Water Heating and Distribution Technologies (SWHDT) Program is to identify and develop technologies that enable the efficient generation and distribution of hot water, thus providing enhanced comfort and measurable energy savings to California residents. The long-term performance goal is to complete activities that will lead to approximately 600 gigawatt hours (GWh) of annual electricity savings for California ratepayers by the tenth year after program completion.

Four technical projects will be completed:

1. 2.1 Combined Refrigerator and Electric Water Heater (CREWH) – Development and commercialization of the CREWH, a hybrid appliance that uses waste heat from a refrigerator to heat domestic water.
2. 2.2 Condensate Recovery System (CRS) – Detailed safety analysis and testing of the CRS, a device to designed to reduce the installed cost of residential heat pump water heaters (HPWHs) and increase the locations in houses where they can be installed.
3. 3.1 Hot Water Distribution Systems (HWDS) – Detailed analysis and evaluation of existing alternate hot water distribution systems in order to identify those that are most efficient for California residential use.
4. 3.2 Rapid Radiant Distribution System (RRDS) – Development and commercialization of a hydronic radiant slab floor heating system that can be rapidly deployed and utilized by production builders. The goal is to streamline the process and reduce costs of installing such radiant heating systems.

This program began in June 2001 and will be completed in August 2004.

This programmatic contract supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by reducing cooling energy use in new and existing buildings, integrating energy-efficient strategies and products with other building elements, searching for the highest value strategies and technologies for retrofit, and creating downsized equipment for multi-family applications.
- Improving the environment, public health and safety by developing ventilation and construction techniques that mitigate moisture and IA problems.
- Providing greater choices for California consumers by increasing consumer load management choices.

Description of Element 1 – Program Administration:
This element encompasses overall coordination and integration of the technical program elements for the SWHDT program. The projects comprising this element include a kick-off meeting, program meetings, annual technical briefings, monthly progress reports, a final report, and a final meeting.

Proposed Outcomes for Element 1:
1. Produce all deliverables on time and within budget.
2. Establish a web site to communicate project results and manage activities.
3. Conduct outreach efforts to facilitate commercialization of results.

Program Status of Element 1:
In addition to program administrative tasks (monthly reporting, Program Advisory Committee meetings, annual technical briefings), Davis Energy Group (DEG) has completed several market connection activities. The website has areas for program support and information distribution - public documents are available at:

⇒ www.davisenergy.com/swhdt/

Description of Element 1 – Efficient Hot Water Generation:
The technical element of this work is to identify and develop technologies that enable the efficient generation of hot water. This element has two projects:

- 2.1) Prototype Development of a Combined Refrigerator and Electric Water Heater (CREWH). This project will develop a cost-effective combined refrigerator and electric water heater that can significantly reduce overall energy consumption in California homes by fully or partially heating domestic water with refrigerator discharge heat, simultaneously delivering "free" cooling to the kitchen. After conducting feasibility studies, two different CREWH prototypes will be built, tested and evaluated.
- 2.2) Safety Analysis & Testing of Heat Pump Water Heater Condensate Recovery System (CRS). This project will obtain laboratory evidence supporting the safety of injecting sterilized condensate from a residential heat-pump water heater into the water storage tank. Project tasks include conducting a preliminary hazard analysis, designing a test apparatus, and fabricating and testing the prototype technology.

Proposed Outcomes for Element 2:
1. An understanding of the economic feasibility of applying CREWH technology to particular California residential applications.
2. New baseline product information about commercializing the CREWH technology by constructing two full-scale prototype units.
3. Expected energy savings from implementing the optimal CREWH configuration.
4. Structured laboratory investigation of the health risks associated with injecting heated condensate from a heat pump water heater back into the storage tank.

Program Status of Element 2:
Project 2.1: Two CREWH prototypes have been designed and produced in consultation with Maytag. The second prototype is currently undergoing field testing.

Project 2.2: The preliminary hazard analysis, laboratory test plan, fabrication report, laboratory test report and a final project report have been completed. The analysis of the CRS technology completed by TIAX, LLC indicated any safety issues for residential use should be negligible. This project is complete.

Description of Element 3 – Efficient Hot Water Distribution:
The technical element of this work is to identify and develop technologies that increase the efficiency of hot water distribution. The element has two projects:

- 3.1) Evaluation of Alternate Hot Water Distribution Systems (HWDS): The HWDS project evaluates performance and economic benefits of existing domestic hot water distribution systems that can improve energy efficiency of hot water delivery in California residences. Potential energy savings, a cost-benefit analysis, and market barriers for alternative new systems will be performed.
- 3.2) Development and Demonstration of a Rapid Radiant Distribution System: The RRDS research will develop system concepts for installing radiant hydronic floor systems faster. Preferred concepts will be chosen, product requirements defined and prototype RRDS arrays installed. A production readiness plan will also be prepared.

Proposed Outcomes for Element 3:

1. An understanding of alternative domestic hot water distribution systems that will increase energy efficiency in California residences.
2. A demonstration to the building industry that radiant hydronic distribution systems can be installed three to four times more quickly than current practice.

Program Status of Element 3:

1. Project 3.1: ORNL used material properties, component geometry, insulation and other relevant system parameters to construct a computer model for simulating three types of plumbing systems (conventional, recirculation and parallel-pipe manifold), and simulated seven representative house plans. This project is complete.
2. Project 3.2: DEG surveyed industry professionals and observed actual construction to identify market barriers to the installation of hydronic radiant slab systems by production builders. They developed a modular concept that includes offsite attachment of radiant tubing to welded wire mesh using special jigs, an automatic tying tool to reduce installation onsite labor, and risers to correctly position the mesh vertically within a concrete slab. A field demonstration of this prototype RRDS concept was completed during summer of 2003. This project is complete.

Program Status:
All program activities will be completed and the Final Report will be published in the first half of 2005.

BLDGS Projects Completed in 2004

Alternatives to Compressor Cooling: Phase V - Integrated Ventilative Cooling

Contract #: 500-98-024
Contractor: Davis Energy Group, Inc.
Subcontractors: Berkeley Solar Group : Loisos/Ubbelohde : Pacific Gas and Electric Company : ZTECH : Bruce Hackett : Loren Lutzenhiser
Contract Amount: $713,246
Match Amount: $150,437
Contractor Project Manager: David Springer (530) 753-1100
Commission Contract Manager: Philip Spartz P.E. (916) 654-4592
Status: Completed

Project Description:
The purpose of this project is to reduce the peak load of new single-family homes in California transition (mild) and inland climates by using night ventilation cooling to eliminate or substantially reduce compressor-based air conditioning. Other benefits of night ventilation cooling include energy savings, wintertime fresh air ventilation, enhanced security, air filtration for improved indoor air quality, and automatic operation that is quieter than standard forced-air systems.

In this contract (the current phase of a multi-year research program), contractor Davis Energy Group developed a heating, ventilation and cooling (HVC) unit called "NightBreeze" that integrates heating, cooling, ventilation cooling, and fresh air ventilation. The project also constructed and monitored two new homes, designed for optimal summer performance, which use the HVC unit to provide filtered cool night air to the house in lieu of or in addition to central air conditioning. Previous phases of this work developed "Summer Performance Home" architectural design improvements such as increased thermal mass (50% tiled slab floor and 5/8" thick drywall throughout), use of a radiant barrier in the attic, insulated slab edges, and exterior shading of south and west windows.

This project supports the PIER Program objectives of:
- Improving the reliability/quality of California's electricity by reducing peak electrical demand created by compressor-based air conditioning.
- Improving the energy cost/value of California's electricity by reducing energy use and costs created by residential space cooling during summer "heat storms."
- Improving the environment, public health and safety by improving indoor air quality through the HVC unit that automatically introduces filtered cool night air into residences without the need to open windows.

Proposed Outcomes:
1. Develop and demonstrate "integrated ventilation cooling" in two homes in sites representative of transition and inland valley climates (Climate Zones 3 and 12).
2. Develop and refine an integrated, variable-speed, hydronic heating and ventilation-cooling fan coil with damper system, and associated intelligent controls.
3. Demonstrate 100% peak demand savings and 74% energy savings in Climate Zone 3, and 37% demand savings and 60% energy savings in Climate Zone 4.
4. Maintain indoor air quality consistent with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) ventilation standard 62-1989.

Actual Outcomes:

1. Summer Performance Home design principles were successfully demonstrated in homes in Watsonville and Livermore. The houses were monitored for more than one year. The Watsonville house (transition climate zone 3) maintained comfortable temperatures without air conditioning installed. The Livermore house (inland valley climate zone 12) operated its two air conditioners a combined total of 7.4 hours (average of less than 3 minutes per day) during the summer of 2003, which included 15 days with temperatures over 100 degrees F.
2. An integrated heating, ventilation cooling, air conditioning and fresh air ventilation system ("NightBreeze") was built, tested, and successfully demonstrated. The system includes a hot water air handler, damper, and controls. The air handler utilizes an electronically commutated motor (ECM) that provides quiet variable speed heating, ventilation cooling, and fresh air ventilation fan energy use for heating that is less than half that of typical gas furnaces. An outside air damper (economizer) selects between outside air and return air, filters both, and provides air relief to the outside so that windows do not have to be opened. A "user friendly" wall display unit (thermostat) integrates control of all heating, ventilation cooling, air conditioning, and fresh air ventilation functions. The wall display unit predicts future temperature conditions in order to provide information to the user about optimal comfort settings, adjusting ventilation cooling rates to minimize fan energy use, avoiding overcooling, and minimizing standard air conditioner operation.
3. The specific demand reduction and energy savings goals for Climate Zones 3 and 12 described in the project proposal were substantially achieved. The proposed goal of reducing peak load by 100% in Climate Zone 3 was verified by the Watsonville demonstration house, which maintained comfort without standard vapor compression air conditioning. The 74% energy savings proposed for Climate Zone 3 could not be demonstrated because air conditioning energy use for a standard house built to Title 24 standards in that zone is almost non-existent. In retrospect, Climate Zones 2 or 4 would have been better subjects for demonstration of Alternatives to Compressor Cooling (ACC) design strategies in transition climates. The performance goals for Climate Zone 12 were exceeded, with a 50% peak demand reduction and 70% energy savings established by monitoring and simulations of the Livermore house.
4. Winter fresh air ventilation with the "NightBreeze" system precisely meets ASHRAE Standard 62 air change requirements while using less fan energy than any other mechanical fresh air system available.

Project Status:

This contract is complete.
Final Report Title: Alternatives to Compressor Cooling, Phase V: Integrated Ventilation Cooling
Publication Number: 500-04-009
Publication Date: February 2004
PIER Web Location: www.energy.ca.gov/pier/final_project_reports/500-04-009.html

A follow-on PIER contract is further developing the NightBreeze ventilation cooling technology for integration with gas furnace-based systems and service to multiple zones from a single system (see PIER contract 500-02-026). More information on this hydronic ventilation cooling technology is available at:

⇒ www.davisenergy.com/nb_page.htm

Assessing Building Vulnerability to Chemical and Biological Threats

Contract #: 500-01-034
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $250,000
Contractor Project Manager: Richard Sextro (510) 486-6295
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Completed

Project Description:
Preparation and advanced planning can reduce the likelihood and severity of chemical, biological, and radiological attack. However, it can be difficult for building managers to determine key vulnerabilities and prioritize implementation of mitigation strategies, because most information that treats these subjects is intended for technical consultants or design professionals. The purpose of this project was to develop a set of guidelines and assessment procedures to aid consultants and facility managers in assessing and reducing building vulnerabilities for public- and private-sector buildings across California. The mitigation methods were guided by the related goals of improving energy efficiency and indoor air quality.

This project supports the PIER Program objective of:
- Improving the environment, public health and safety by providing tools to protect buildings against chemical and/or biological attack, while minimizing the impact on building energy use.

Proposed Outcomes:
1. Develop and test procedures for assessing the vulnerability of buildings to chemical or biological agent attack, including the impact on building energy systems.
2. Produce a guidance document for vulnerability assessment and mitigation for high profile buildings to reduce the likelihood and effectiveness of potential attacks, with consideration for impacts on the building energy systems.

Actual Outcomes:
1. The research team developed and tested procedures for assessing the vulnerability of buildings to chemical and biological attack.
2. The Building Vulnerability Assessment and Mitigation Program (BVAMP) now provides facility managers with an easy-to-use software tool for identifying basic steps to secure buildings and develop building specific mitigation plans. BVAMP develops building-specific advice for:
    - Improving emergency preparedness.
    - Developing building system control protocols for use during emergencies.
    - Planning for shelter-in-place responses.
    - Restricting access to building systems and information.

Project Status:
The project is complete and the assessment tool is available at:
⇒ http://securebuildings.lbl.gov/BVAMP.html
The project Final Report will be released in the first quarter of 2005.

Building Specification Guidelines for Energy Efficiency

Contract #: 500-98-027
Contractor: Eley Associates, Inc.
Subcontractors: Taylor Engineering : Cathrine Cooper : SMWM : SDV/ACCI : After Image : John Raeber
Contract Amount: $233,280
Contractor Project Manager: Charles Eley (415) 957-1977
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Project Description:
The purpose of this project is to develop reference construction specifications to encourage the use of energy-efficient equipment and technologies in commercial buildings. The focus is on efficient, cost-effective equipment and technologies that lack adequate or well-known information. This project is lowering the barriers to specifying energy efficient equipment and technologies for commercial buildings by:

- Simplifying the specifications of some technologies.
- Addressing project commissioning and monitoring within each of the technologies.
- Providing specifications for advanced cost-effective technologies.
- Addressing integrated controls and open protocols for commercial lighting and heating, ventilating and air conditioning (HVAC) systems.
- Disseminating the new specifications to the construction industry through the Internet.

The specifications have been tested by the Contractor's team, reviewed by building design professionals, and made available on the Internet. The format facilitates the use and incorporation of the specifications into construction documents by design professionals. In addition, they help equipment manufacturers to understand what they need to build to satisfy the efficiency market.

This project supports the PIER Program objective of:

- Improving the energy value of California's electricity by influencing standard construction practices to reduce future building and system energy use in the commercial sector while also promoting better occupant health and comfort.

Proposed Outcomes:

1. The specifications will promote energy efficient design of commercial buildings by providing a comprehensive and integrated source for up-to-date information on the most efficient and cost effective equipment, technologies and operating strategies.
2. Reduce annual building system (e.g., lighting, HVAC) energy costs of the building whose design used the specifications by at least 5 percent.

Actual Outcomes:

1. The specifications promote energy efficient design of commercial buildings by providing a comprehensive and integrated source for up-to-date information on the most efficient and cost effective equipment, technologies and operating strategies.
2. If followed, the specifications would likely reduce annual building system (e.g., lighting, HVAC) energy costs of a building by at least 5 percent.

Project Status:
The final revision of the specifications is available for download from the contractor's website:

⇒ www.eley.com/specs/

Final Report Title: Reference Specifications for Energy and Resource Efficiency
Publication Number: 500-04-015
Publication Date: March 2004
PIER Web Address: www.energy.ca.gov/pier/buildings/projects/500-98-027-0.html

California Commissioning Collaborative

Contract #: 500-02-030
Contractor: Portland Energy Conservation, Inc.
Contract Amount: $195,000
Contractor Project Manager: Phil Welker (503) 595-4475
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The California Commissioning Collaborative (CCC) is a long-term multi-sponsor program dedicated to increasing the practice of building commissioning in California. The CCC promotes commissioning education, training, stronger building codes and commissioning standards in the new and retrofit markets. CCC members are working to address the barriers to commissioning in an effort to improve the energy efficiency, comfort and indoor air quality of public and private commercial buildings. Portland Energy Conservation Incorporated (PECI) is currently administering the CCC. This collaborative research agreement will formalize the PIER Buildings Program's participation in the CCC.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by increasing building energy efficiency through the processes of new and retro-commissioning.

Proposed Outcomes:

1. The California Commissioning Collaborative will conduct outreach activities, including the market transfer of PIER's commissioning-related research, to broadcast the benefits of commissioning.
2. The California Commissioning Collaborative will critically review and shape the research products resulting from California's publicly-funded building commissioning-related R&D.
3. The California Commissioning Collaborative will support the development of the equipment acceptance requirements that will be included in the 2005 Nonresidential Building Energy Efficiency Standards (Title-24).

Actual Outcomes:

1. Conducted outreach activities, including the market transfer of PIER's commissioning-related research, to broadcast the benefits of commissioning. An on-line library of commissioning-related documents has been developed. These documents will provide the background research needed to convince building owners and operators of the benefits of commissioning as well as research needed to develop tools for commissioning providers. The mechanism to produce quarterly news briefs has also been developed. These news briefs will communicate the most up-to-date information in the commissioning industry to all interested parties.
2. Critically reviewed the research products resulting from California's publicly funded building commissioning-related R&D.
3. Developed and field-tested the equipment acceptance requirements that will be included in the 2005 Nonresidential Building Energy Efficiency Standards (Title-24).

Project Status:
This project is complete. The on-line library and other relevant commissioning information are available at the California Commissioning Collaborative website:

⇒ www.cacx.org

Design Refinement and Demonstration of a Market-Optimized Residential Heat-Pump Water Heater

Contract #: 500-98-028
Contractor: TIAX LLC
Subcontractors: EnviroMaster International
Contract Amount: $756,095
Match Amount: $300,000
Contractor Project Manager: Robert Zogg (617) 498-6081
Commission Contract Manager: Philip Spartz P.E. (916) 654-4592
Status: Completed

Project Description:
The purpose of this project was to design, test and demonstrate a market-optimized residential electric heat pump water heater (HPWH). The primary objectives of this project were to:

1. Reduce its total installed cost from $1,200 to $875 by reducing both the manufacturing and installation costs of the HPWH unit.
2. Make the water heater capable of achieving at least a 2.0 energy factor, the standard performance measure for water heaters used by the U.S. Department of Energy (DOE).
3. Address reliability and durability concerns.

With funding provided by DOE, Oak Ridge National Laboratory (ORNL) provided durability testing on ten prototypes under laboratory conditions simulating ten years of normal operation. The TIAX team, in cooperation with several California utilities, field-tested twenty prototype units in residences throughout the State.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing a low-cost, highly reliable and durable residential heat-pump water heater.

Proposed Outcomes:

1. Reduce the total installed cost of residential heat pump water heaters from $1,200 to $875 (based on annual production volumes of 10,000 units or more).
2. Design, test and demonstrate a heat-pump water heater capable of achieving at least a 2.0 Energy Factor using the water heater testing procedure prescribed by DOE.

Actual Outcomes:

1. Using costs supplied by manufacturing partner EMI and based on their projection to annual production volumes of 10,000 units or more, the total installed cost of the residential HPWH developed under the project is between $1,100 and $1,200. This is primarily due to manufacturing costs. A public production readiness plan with additional relevant economic information has been produced. Installation costs for the field test units were generally much closer to the original goal, as the HPWH was designed to be a "drop-in" replacement for a conventional electric water heater and has nearly the same physical dimensions – 60" inches tall and 22.25" in diameter. Half of the field test installations were straightforward, ranging between 4.5 and 6 hours. No installation required more than 8 hours.
2. The HPWH tested according to the DOE Energy Factor laboratory procedure gave a result of 2.4 ten units measured by ORNL with a slightly modified test gave factors ranging from 1.8 to 2.1. Average energy savings of the 20 units was 35.9%, based on a comparison with simulated electric-resistance water-heater performance.

3. Reliability of the field test units was not as good as hoped for at the outset, primarily due to control issues with the field tested prototype units. Most test units were regarded favorably by homeowners.
4. Manufacturer EMI has been marketing their HPWH product under the "WatterSaver" brand. Product information is at:
   ⇒ www.enviromaster.com/watter_saver/
   California's potential market share of this electric technology is about the same size as neighboring states that depend almost entirely on electric-resistance units for domestic water heating. An information dissemination plan discussing promotion of the technology was written for the project.

Project Status:
The project is complete.
Final Report Title: Design Refinement and Demonstration of a Market-Optimized, Residential Heat-Pump Water Heater
Publication Number: 500-04-018
Publication Date: April 2004
PIER Web Location: www.energy.ca.gov/pier/buildings/projects/500-98-028-0.html

Development of an Advanced Indirect Heat Exchange Module

Contract #: 500-98-022
Contractor: Davis Energy Group, Inc.
Subcontractors: Pacific Gas and Electric Company : Refrigeration Technology, Inc. : CoolSmart LLC : James Ramos & Associates
Contract Amount: $248,719
Match Amount: $136,169
Contractor Project Manager: Richard Bourne (530) 753-1100
Commission Contract Manager: Philip Spartz P.E. (916) 654-4592
Status: Completed

Project Description:
The purpose of this project was to design an improved version of an indirect-direct evaporative cooler (IDEC) with better efficiency, cost, and reliability than previous designs. The researchers developed an optimized indirect heat exchanger to allow better airflow than previous two-stage evaporative cooler designs, and a new cabinet design to improve maintainability. A survey of two-stage evaporative cooler owners was conducted to provide input on the new design, and prototypes were laboratory-tested to assess their performance.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by developing an air conditioning technology that contributes considerably less to peak electrical demand than conventional air conditioning units.
- Improving the energy cost/value of California's electricity by refining a new energy efficiency technology to make it more market ready.

Proposed Outcomes:

1. Improve design flexibility by developing an improved indirect heat exchanger with potential for variable assembled width to provide a range of cooling capacities.
2. Improve design quality by eliminating adhesives in the heat exchanger assembly, and by eliminating leakage and corrosion using a molded cabinet with top mount blower.
3. Reduce initial cost by $300 using 1) a one-piece molded cabinet with integral blower housing and water sump, and 2) a more rapid heat exchanger fabrication process.
4. Lower operating costs at least 5% by increasing evaporative effectiveness and reducing power consumption versus a second-generation IDEC design.

Actual Outcomes:

1. At project completion, the researchers developed and tested a new counterflow heat exchanger with superior performance. The innovative indirect heat exchanger uses a variable number of plate pairs that can be assembled quickly to any desired width to provide different amounts of cooling capacity.
2. The project achieved a projected cost savings of $386 per unit, exceeding the original goal. This amount will likely translate to a $600 to $800 reduction in price to the purchaser, substantially enhancing IDEC marketability.
3. Test results show that overall evaporative effectiveness of the new unit exceeds the second-generation IDEC design by 9.5%. Overall efficiency gains were even more impressive. Across a comparable speed range, Energy Efficiency Ratios (EERs) for the new design averaged 90% higher than the second-generation unit.
4. The researchers used a MICROPAS two-stage evaporative cooler model, in conjunction with test data, to compare IDEC and conventional cooling system performance for two

building types in eight California climate zones. The analyses estimated 89 to 95% IDEC annual energy savings potential, accompanied by 80 to 89% peak demand savings.

Project Status:
The project is complete.
Final Report Title: Development of an Improved Two-Stage Evaporative Cooling System
Publication Number: 500-04-016
Publication Date: March 2004
PIER Web Location: www.energy.ca.gov/pier/buildings/projects/500-98-022-0.html

One-page Fact Sheet Title: Gen3 Indirect-Direct Evaporative Cooler
Web Location: www.davisenergy.com/pdf/IFS0603.pdf.

U.S. Patent: 5,664,433 (Issued September 1997).

Energy Efficient and Affordable Small Commercial and Residential Buildings for a Growing California

Contract #: 400-99-011
Contractor: Architectural Energy Corporation
Subcontractors: Battelle Northwest Laboratories : The National Institute of Standards and Technology : Purdue University : Massachusetts Institute of Technology : Oak Ridge National Laboratory : Schiller Associates : Heat-Timer Corporation : Newport Design Consultants.
Contract Amount: $5,422,000
Match Amount: $6,387,000
Contractor Project Manager: Donald Frey (303) 444-4149
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Program Description:
The purpose of the Energy Efficient and Affordable Small Commercial and Residential Buildings Program was to develop and demonstrate technologies to improve energy efficiency. The program addressed such issues as peak electrical demand, healthful indoor environments, and California building affordability. It also strengthened the energy efficiency industry in California by providing new jobs and growth opportunities for companies that provide technology, systems, software, design, and building services. High impacts and direct benefits for every research dollar were provided by projects that are synergetic, market-oriented, and supported by industry. The Program consisted of 6 elements, each element with one or more projects.

This programmatic contract supports the PIER Program objectives of:

- Improving California's economy by stimulating the development of new marketable energy-efficient technologies and by reducing energy expenses, leaving more financial resources for other uses.
- Improving the reliability and quality of California's electricity by reducing peak demand, leading to lower infrastructure costs and better reliability.
- Improving California's natural environment by reducing air pollution and water use related to energy production.

Description of Element 1 – Program Management:
This element provided program administration for all technical elements and overall coordination and integration of all the subcontractors and work tasks. The prime contractor managed the technical work in addition to handling all administrative activities. This element also included outreach efforts to establish market connections between the research teams and industry.

Proposed Outcomes for Element 1:

1. Manage industry and public advisory groups to maximize practical input.
2. Establish public and team web sites to communicate project results and manage project activities.
3. Conduct outreach efforts to facilitate adoption in the marketplace.

Actual Outcomes from Element 1:

1. The contractor web site is fully operational with descriptions of each project. Final project reports and major deliverables are also available for download at the site at:
   ⇒ http://aes1.archenergy.com/cec-eeb/

2. A Project Advisory Committee of involved professionals was formed and has had approximately 10 meetings, providing input and guidance as needed. A multi-day meeting sponsored by the program and devoted to diagnostics tools was attended by representatives from controls companies, research organizations, utilities, government and publicists.
3. Biweekly conference calls with key members of the technical teams were held to assess and maintain project progress and solve problems.
4. Regular monthly reports, critical project reviews, and two annual reports and a final report were generated.

Description of Element 2 – Automated Commissioning and Diagnostics:
This program element's work scope involves the following technical projects:

- Fault Detection and Diagnostics for Rooftop Air Conditioning diagnoses problems automatically using sophisticated algorithms to compare reference performance with actual performance. Ultimately the software is expected to be incorporated into unit controllers.
- Equipment Scheduling and Cycling used a Non-Intrusive Load Monitor (NILM) located at a power service entrance or motor control center to automatically identify which equipment is operating at a given time and how much energy it is consuming. It can also be used to identify malfunctioning equipment.
- Air Handling Unit and VAV Box Diagnostics use rule based and statistical analysis techniques to automatically detect problems in these devices. The diagnostic algorithms are embedded in the unit controllers to reduce control system communication requirements.
- Demonstration of the Whole Building Diagnostician (WBD) involved field testing of this software tool, which is currently able to diagnose problems and estimate economic impacts of air handler economizer faults.
- Pattern Recognition Based Fault Detection and Diagnostics is an extension of the ENFORMA diagnostic tool, enabling it to automatically draw conclusions about the performance of boilers, chiller plants, and cooling towers.
- Enhancement of the Whole Building Diagnostician (WBD) extended the energy analysis capabilities of the WBD, allowing peer comparisons between different buildings and normalizing performance based on user defined variables.
- Enabling Tools for testing the Whole Building Diagnostician (WBD) on the Virtual Cybernetic Building Testbed, allowed the WBD to process information from a simulated building mechanical system, including various simulated equipment faults, to test the WBD's ability to detect those faults.

Proposed Outcomes for Element 2:

1. Development and demonstration of FDD will accelerate commercialization and deployment and ultimately result in energy and comfort benefits in buildings with package rooftop equipment.
2. NILM development and deployment will lead to improved equipment operation, fault detection, and equipment energy use.
3. VAV and AHU diagnostics integrated with building control systems will lead to load reductions and better comfort in buildings where deployed.
4. WBD deployment will allow automatically diagnosis of the nearly ubiquitous outside air economizer problems. The WBE enhancement will allow flexibility in relating energy consumption to variables other than temperature.

5. Pattern recognition based software will facilitate operator response in repairing central plant equipment.
6. The enabling tools will be valuable to developers of diagnostic tools for product testing.

Actual Outcomes from Element 2:

1. The AHU and VAV box diagnostics and the Rooftop Unit Diagnostics have entered a final development stage for commercialization. Significant market partners in the controls industry are in collaboration, and several of them are expected to develop commercial releases if the results are favorable.
2. The WBD and WBE have undergone field testing at 3 sites in California. The contractor is pursuing further demonstrations with federal funding.
3. Several of the technologies, including the pattern recognition techniques and the AHU diagnostics have been selected for incorporation in a 'diagnostic server' application which will be made available to owners and second party service providers. A multinational controls company is extremely interested in the product.
4. A small technology company is being formed to produce and market the NILM.

Description of Element 3 –Advanced Load Management and Controls:

This program element's work scope involves the following technical projects:

- Demand-Controlled Ventilation (DCV) Assessment analyzed the potential of carbon dioxide (CO_2) sensors to replace fixed ventilation requirements in order to improve indoor air quality and save energy. It also identifies specific applications and climate zones where DCV will have the best potential.
- Night Ventilation with Building Thermal Mass investigated the use of cool night air to cool the mass of a building, which can lower the need for cooling during hot daytime hours and reduce peak electric loads. It also investigated applications of mechanical pre-cooling strategies.
- Smart Load Control and Grid-Friendly Appliances are devices which can detect conditions of electrical system stress and automatically turn off appliances in response. This project investigated the feasibility of local grid stress detection.
- Extending BACnet for Lighting and Interfacing Building Systems with Utilities developed the ability of BACnet facility management systems to control lighting loads and to respond to price or load shedding signals from utilities.
- Aggregated Load Shedding using Non-Intrusive Load Monitor (NILM) investigated the ways buildings can reduce electrical demand while still maintaining comfort conditions.

Proposed Outcomes for Element 3:

1. Use of Demand Control Ventilation and Nighttime Cooling will reduce energy use, demand, and potentially improve indoor air quality in buildings.
2. Extensions of BACnet will facilitate intelligent control of more of a buildings functions leading to better demand responsiveness and grid reliability.

Actual Outcomes from Element 3:

1. Both DCV and Nighttime Cooling are being evaluated by a major controls company for integration with its controllers. Guidelines for DCV are helping designers to understand what situations make sense for this control scheme, and which climate zones offer the best opportunities. Nighttime cooling strategies will be integrated with mechanical cooling strategies to reduce peak loads.

2. Lighting and Utility Industry coordination and software standards were developed by the BACnet standards group. The standards are now being used to develop and upgrade commercial products.

Description of Element 4 from Alternative Cooling Technology and Strategy:
This program element's work scope involves the following technical projects:

- Assessment and Field Testing of Ventilation Recovery Heat Pumps.
- Residential Hydronic Radiant Heating and Cooling System Demonstration.
- Design Methods and Guidelines for Natural Ventilation in California.

Proposed Outcomes for Element 4:

1. The residential radiant hydronic heating and cooling system investigation will demonstrate the potential benefits this building method provides for demand and energy reduction, which may lead to more widespread acceptance of this type of comfort control system.
2. Software tools for modeling of naturally ventilated buildings may lead to more widespread development and use of low energy natural and hybrid ventilation systems.

Actual Outcomes from Element 4:

1. Field testing and calibration of simulation models for ventilation recovery heat pumps were conducted in California schools. This equipment was shown to have little or no benefit in most California climates.
2. Comparison of energy use and comfort characteristics was made of a house using various combinations of forced air and hydronic radiant slab heating and cooling. The conclusion is that the technique of hydronically cooling floor slabs has an enormous potential to reduce peak cooling loads in California. Floor temperatures are not low enough to produce condensation or comfort problems. Night ventilation, which cools other parts of the building mass, enhances the cooling demand reduction.
3. A report on prior work along with a suitability analysis for California climates is aiding designers in knowing where to use this technique in California. The natural ventilation software design tool was submitted to expert review, which found it useful in design of a Santa Cruz school. Further development of the tool is ongoing.

Description of Element 5 – Energy Efficient Construction Technology:
This program element's work scope involves the following technical task:

- Building-Integrated Photovoltaics investigates the effects on PV performance when they are integrated with vertical building envelope components. Some of the potential factors are orientation, shading and temperature effects.

Proposed Outcome for Element 5:

1. This project quantifies the performance expectations for photovoltaic cells when integrated into residential and commercial building curtain wall construction, which will lead to more accurate design information.

Actual Outcome from Element 5:

1. The photovoltaics were installed and the performance monitored and analyzed. The project uncovered significant inaccuracies in widely used simulation software. The project also determined that vertically oriented photovoltaics are generally not cost effective.

Description of Element 6 – Impact Assessment of Project Results:
This program element involved the development of a standard methodology for predicting energy impacts of technology development and adoption.

Proposed Outcome for Element 6:

1. By assessing the potential impacts of projects or developments on energy use in California this project will help to guide where scarce research funds can provide the maximum benefit.

Actual Outcome from Element 6:

1. The methodology was developed and presented for review. The method may prove to be useful for assessing the future benefits of technological innovations.

Program Status:
All program activities have been completed.
Final Report Title: Energy Efficient and Affordable Commercial and Residential Buildings Program
Publication Number: 500-03-096
Publication Date: November 2003
Final Report Attachments Associated with this Project:

- Building Integrated Photovoltaics
- AHU and VAV Box Diagnostics
- Enabling Tools
- Demand Controlled Ventilation Assessment
- Link to the Attachment Page
- Fault Detection and Diagnostic for Rooftop Air Conditioners
- Enhancement of the Whole Building Diagnostician
- Smart Load Control and Grid-Friendly Appliances
- Aggregated Load Shedding
- Design Methods and Guidelines for Natural Ventilation
- Ventilation Energy Recovery Heat Pump Assessment
- Equipment Scheduling and Cycling
- Pattern Recognition Diagnostics
- Residential Hydronic Radiant Cooling and Heating Assessment
- Whole Building Diagnostician Demonstration
- Night Ventilation with Building Thermal Mass
- Extending BACnet for Lighting and Utility Iterfacing
- Impact Assessment Framework

PIER Web Address: www.energy.ca.gov/pier/buildings/projects/400-99-011-1.html

Instrumented Home Energy Rating and Commissioning

Contract #: 500-98-033
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $710,000
Match Amount: $137,000
Contractor Project Manager: Max Sherman (510) 486-4022
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Project Description:
The purpose of this project was to develop residential building commissioning guidelines and to demonstrate the value of commissioning services on residences in California. The energy performance of the most significant systems and components of a building were evaluated, and diagnostics and audit tools developed for use in commissioning these systems and components. A set of guidelines for applying the diagnostic tools was developed. These guidelines provide the groundwork for a residential commissioning industry.

This project supports the PIER Program objectives of:

- Improving the value of California's electricity by helping consumers optimize the energy consuming systems in their home to perform at optimal efficiency.
- Strengthening the California economy by creating jobs in the commissioning field while increasing the disposable income of Californians by reducing their energy costs.
- Improving the reliability of California's electrical supply by reducing residential peak electrical demand.

Proposed Outcome:

1. This project will provide information essential for developing a residential commissioning industry in California. A typical California house has 28 percent duct leakage, is 15 percent low on refrigerant charge, and has only 85 percent of needed evaporator airflow. Diagnosing and repairing the systems in this typical house will reduce electricity use by 14-18 percent while providing a more comfortable and healthful indoor environment. Peak electrical demand will typically be reduced by 22-24 percent.

Actual Outcomes:

1. Commissioning guidelines were completed.
2. An annotated bibliography on building commissioning was completed.
3. A draft metrics and diagnostics report was completed.
4. Laboratory and field study work was completed.
5. Four Project Advisory Committee (PAC) meetings and one user workshop were held.

Project Status:
The project has been completed.
Final Report Title: Instrumented Home Energy Rating and Commissioning
Publication Number: 500-04-012
Publication Date: February 2004
PIER Web Location: www.energy.ca.gov/pier/buildings/projects/500-98-033-0.html

Integrated Energy Systems-Productivity and Building Science

Contract #: 400-99-013
Contractor: New Buildings Institute, Inc.
Subcontractors: Heschong Mahone Group : Eley Associates, Inc. : Architectural Energy Corporation : GARD Analytics, Inc. : RLW Analytics, Inc.
Contract Amount: $5,876,972
Contractor Project Manager: Cathy Higgins (509) 493-4468
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Program Description:
The purpose of the Integrated Energy Systems Productivity and Building Science Program is to promote develop energy-efficient systems solutions through integrated systems research. The project has one administrative element and six technical elements. Each technical element is designed to fill major gaps in the existing body of building science knowledge. It is not the individual component, but how they are assembled into and operated within a building system, that determines energy efficiency. The contract term of the technical projects is August 2000 to August 2003, with the contract completion by March 31, 2004.

This programmatic contract supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by allowing energy-saving measures to be integrated into the early design of a building, thereby making energy-efficient measures more cost effective.
- Improving the reliability/quality of California's electricity by reducing peak demand and improving load factor, leading to reduced infrastructure costs and system reliability risks.
- Improving the State's economy by developing energy-efficient solutions that also increase worker/student productivity or increase retail sales.

Description of Element 1 – Administration, Management and Market Connections:
The purpose of this element is to provide program administration for all technical elements and provide overall coordination and integration of all the subcontractors and work tasks. The prime contractor manages the technical work in addition to handling all administrative activities (e.g., contracts, billing, reporting, tracking, etc.) to ensure that all tasks are completed within allocated budget and schedule. This element also includes outreach efforts to establish market connections between the teams completing the research and the users of the research results.

Proposed Outcomes for Element 1:

1. Deliverables on time and within budget.
2. Public and team web sites to communicate project results and manage project activities.
3. Outreach efforts that facilitate adoption in the marketplace.

Actual Outcomes from Element 1:
NBI completed the final report for the technical projects in October 2003 (publication number: P500-03-082) and it is posted on the PIER Buildings Program web site (www.energy.ca.gov/pier/reports/500-03-082.html), together with 33 attachments that include several design guidelines, numerous project reports, and technical appendices. In addition to completing the final report, NBI conducted extensive administrative tasks (manage subcontracts, issue bills, and produce reports) completed numerous activities related to market connections. Most of the detailed findings and documents can be found on the contractor's website (www.newbuildings.org/pier).

Description of Element 2 – Productivity and Interior Environments:
The purpose of this element is to establish actual measurements of the productivity and energy values of daylighting, natural ventilation and high quality lighting in the operation of commercial buildings. The project also seeks to establish and refine a field methodology that can successfully make a compelling association between human performance criteria and building characteristics. Validation and quantification of the productivity value of energy efficiency measures will likely motivate decision-makers to include these measures in buildings. The researchers are investigating these issues in the following facility types: schools, retail outlets, and offices.

Proposed Outcomes for Element 2:

1. Data correlating reduced building energy costs with improved student performance, increased retail sales, and improved office and manufacturing worker productivity.
2. Reduce whole building energy use by increasing use of daylighting by motivating decision-makers to demand daylighting in their buildings.
3. Develop a field methodology that can successfully link human performance to building characteristics.

Actual Outcomes from Element 2:
The final task reports are complete with major findings including:

1. Task 2.2, Reanalysis of Daylighting in Schools study (publication number: P500-03-082-A3): 1) The lowest possible estimate for the impact of daylight on student learning is a 7 percent increase in learning rates between those classrooms with the least to the most daylight. The highest estimate is 37 percent. 2) Daylighting conditions, operable windows and air conditioning were not significant in predicting student absences.
2. Task 2.3, Daylighting and Retail Sales (publication number: P500-03-082-A5): 1) Daylit stores in this chain experienced an average of 0% to 6% increase in sales compared to non-daylit stores. 2) Daylight was found to be as reliable a predictor of sales (as indicated by the partial R^2 for the variables) as other more traditional measures of retail potential, such as parking area, number of local competitors, and neighborhood demographics. 3) During the California power crisis of 2001, when the chain operated its stores at half lighting power, its daylit stores had an average 5.5% increase in sales relative to its non-daylit stores. 4) Along with an increase in average monthly sales, the daylit stores were also found to have 1% to 2% increase in the number of transactions per month. 5) Stores with the most favorable daylighting conditions had a 40% increase in sales compared to non-daylit stores, consistent with the findings of the 1998 study. 6) No seasonal patterns to this daylight effect were observed.
3. Task 2.4, Daylighting in Schools (publication number: P500-03-082-A7): 1) The Daylight Code variable used in the previous schools studies was not significant in predicting student performance for Fresno. 2) The window characteristics have a great deal of explanatory power relative to student performance. 3) The visual environment is extremely important for learning, with significant impacts from view, glare, sun, and sun control. 4) The acoustic environment is extremely important for learning. 5) Poor ventilation and indoor air quality appear to negatively affect student performance. 6) Some classrooms with a high Daylight Code are performing extremely well in Fresno. 7) Operable windows were not found to be associated with better student performance in Fresno.
4. Task 2.5, Daylighting in Manufacturing: Project was cancelled because no suitable project partner was available. The funding was put into Task 2.6, Daylighting in Offices, adding a second test site.

5. Task 2.6, Daylighting in Offices (publication number: P500-03-082-A9): 1) Daylight illumination levels were significant and positive in predicting better performance on a test of mental function and attention. 2) Daylight illumination levels were not significant for the visual acuity tests or long-term memory test. 3) An ample and pleasant view was consistently associated with better office worker performance. 4) Glare from windows was associated with decreased office worker performance. 5) Ventilation and indoor air temperature varied in their impacts on worker performance. 7) The natural log of illumination and the daylight illumination level of the previous hour had the best fit in predicting performance. 8) Physical comfort conditions were an important component of models predicting office worker performance. 9) Office worker reports of better health conditions were strongly associated with better views.
6. The research team presented project results at four conferences.

Description of Element 3 – Integrated Design of Large Commercial HVAC Systems:
The purpose of this element is to develop design guidelines for large commercial heating, ventilation and air conditioning (HVAC) systems, focusing on variable-air-volume systems with chilled water plants. While covering only a minority of all systems installed in California, this is the most common type of large HVAC system and accounts for an estimated 20 to 25 percent of the State's cooling capacity.

This element consists of the following five research projects within the central theme of integrated design of large commercial HVAC systems:

1. Field studies.
2. Building science solutions.
3. Statewide energy impacts.
4. Findings and draft recommendations.
5. Guidelines for integrated HVAC system design.

Proposed Outcomes for Element 3:

1. Develop a set of design guidelines to promote the use of advanced, integrated design strategies in new construction and retrofit projects.
2. Achieve a 25 percent HVAC savings in the target building population, with the total demand savings of about 4.1 megawatts (MW) and energy savings of about 4100 MWh/yr.

Actual Outcomes from Element 3:
The Advanced Variable Air Volume System Design Guide (publication number: P500-03-082-A11) is complete with major findings including:

1. Variable-air-volume (VAV) reheat systems serve approximately 50% of the large office commercial construction market.
2. Implementing strategies in the Design Guidelines will result in HVAC electricity savings estimated to be 25%, corresponding to 12% of total building electricity consumption. Natural gas heating savings are estimated to be 41% of heating energy.
3. Most systems operate at part load the majority of the time. Systems and controls must be designed to be efficient across the full range of operation. This can be achieved by carefully sizing the system components (e.g., terminal units) to make sure they provide comfort and code-required ventilation while limiting the fan and reheat energy at part load. It also requires integrating the controls at the zone to the controls at the air-

handling unit and cooling/heating plants to make the system respond efficiently to changes in demand.

4. Early design issues are most critical.
5. Apply the following key design principles to achieve energy savings:
   1) Reduce design system static pressure.
   2) Employ demand-based static pressure reset.
   3) Use low-pressure plenum returns with relief fans.
   4) Employ demand-based, supply temperature reset to reduce reheat energy and extend economizer effectiveness.
   5) Design fan systems to turn down and stage efficiently.
   6) Optimally size terminal units to balance the energy impacts of pressure drop and minimum air flow control.
   7) Set terminal unit minimums as low as required for ventilation and use intelligent VAV box control schemes to prevent stratification during heating.
   8) Employ demand-based ventilation controls for high-density occupancies.
   9) Design conference rooms and other high-density occupancies to provide ventilation without excessive fan energy or reheat.
   10) Design 24/7 loads to allow efficient system turn down and use of economizer cooling.
6. Project findings have been presented in HPAC Magazine and at American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) conferences held June 2003 and January 2004.

Description of Element 4 – Integrated Design of Small Commercial HVAC Systems:
The purpose of this element is to develop general guidelines for specifying and installing high-performance systems, document statewide savings potentials, and identify future code upgrade options. The project scope includes packaged HVAC systems up to 10 tons per unit—the most common HVAC systems for small commercial buildings in California. Through short-term monitoring and onsite surveys of current practice, the team will identify problems with equipment, controls, distribution systems, and operation and maintenance practices that lead to poor system performance.

Proposed Outcomes for Element 4:

1. Develop an understanding of common practices with equipment and controls (economizers, fan/thermostat, scheduling, etc.), distribution systems, and operation/maintenance practices that lead to poor system performance.
2. Increase energy efficiency and functionality of small commercial HVAC systems by 10 percent through both technical improvements to building design practices and widespread adoption of the improvements identified in the project.
3. Identify future code upgrade options.

Actual Outcomes from Element 4:
The Small HVAC System Design Guide (publication number: P500-03-082-A12) is complete with major findings including:

1. California market analysis: 1) Single package direct expansion (DX) air conditioners are the most popular HVAC system type in new construction in the State, cooling about 44% of the total floor space. 2) The most popular packaged DX system size is 5 tons, with units between 1 and 10 tons totaling about 90% of the total unit sales in new buildings. 4)

Units 10 tons and smaller represent about 58% of the total packaged DX cooling capacity in the State.

2. System performance problems are widespread, impacting building electrical energy performance by an estimated 8% and building natural gas energy performance by an estimated 30%. Based on field studies of 215 HVAC units at 75 sites researches found economizers not operating properly (64% of units), improper refrigerant charge (46%), fans running during unoccupied periods (30%), fan that cycle on and off with a call for heating and cooling rather than providing continuous ventilation air (38%), low air flow (39%), no outside air (8%), actual fan power 20% greater than Title 24, and simultaneous heating and cooling (8%).
3. Numerous opportunities exist for improving efficiency, including improved economizer designs using thermostatic expansion devices, improved air-side efficiency on-board fault detection and diagnostic systems and the use of thermostats appropriate for commercial applications.
4. Reduction in system size on the order of 40% and reduction in annual energy costs on the order of 25% to 30% are possible with simple integrated design strategies.
5. Key actions designers can take to improve the performance of small HVAC systems include:
   - Practice load avoidance strategies such as reduced lighting power, high-performance glass and skylights, cool roofs, and improved roof insulation techniques in the overall building design.
   - Size units appropriately using ASHRAE approved methods that account for the load avoidance strategies implemented in the design, and use reasonable assumptions on plug load power and ventilation air quantities when sizing equipment.
   - Select unit size and air flow based on calculated sensible loads without oversizing. Consider increasing unit flow rate to improve sensible capacity in dry climates.
   - Specify units that meet CEE Tier 2 efficiency standards and incorporate premium efficiency fan motors, thermostatic expansion valves and factory-installed and run-tested economizers.
   - Design distribution systems with lower velocities to reduce pressure drop and noise. Seal and insulate duct systems located outside the building thermal envelope.
   - Operate ventilation systems continuously to provide adequate ventilation air. Incorporate demand-controlled ventilation to reduce heating and cooling loads.
   - Specify commercial-grade thermostats with the capability to schedule fan operation and heating and cooling setpoints independently.
   - Commission the systems prior to occupancy through a combination of checklists and functional testing of equipment control, economizer operation, air flow rate, and fan power.
   - Develop clear expectations about the services provided by HVAC maintenance personnel.
6. The project team presented preliminary results at two conferences and published results in a series of four HPAC Engineering articles. The research team also applied preliminary results to the Title 24 2005 Standards in two ways:
   - Field findings helped to document problems that will be addressed through the Nonresidential Acceptance Requirements proposal.

- Modeling and analysis supported the Nonresidential Duct Sealing and Insulation proposal through PG&E's CASE initiative.

Description of Element 4 – Integrated Design of Commercial Building Ceiling Systems:
The purpose of this element is to develop a prototype integrated ceiling design system with skylights, light wells, photocontrols, electric lighting and air distribution components. To support this effort the team is:

- Conducting new tests for horizontal skylight thermal and light transmission properties, which is expected to lay the groundwork for long-delayed test standards for skylight/light-well combinations.
- Conducting a field study to assess the persistence and effectiveness of insulation installed on top of dropped ceilings.

Proposed Outcomes for Element 5:

1. Develop an advanced ceiling system that offers superior energy performance and lighting quality while incorporating an extremely efficient lighting system, which includes skylights and photocontrols.
2. Create design guidelines ready for dissemination through the market transformation programs to designers and building owners.
3. Perform an analysis to show whether Title 24 might reasonably consider toplighting as part of baseline construction practice.
4. Develop skylight test protocols for U factor, visible light transmittance, and solar heat gain coefficient and skylight photometry.

Actual Outcomes from Element 5:

1. Design Guidelines for Skylights with Suspended Ceilings (publication number: P500-03-082-A13) is complete with major findings including:
   - Designers can use the Design Guidelines to create a custom skylight/light-well system for their projects. In addition, the Design Guidelines' valuable coordination and integration information will help facilitate the designers work with other construction professionals. For the manufacturer, the Design Guidelines communicate system design, component requirements, code and performance metrics, and market information about modular skylight systems and the market benefits of providing such a product.
   - Splayed light wells allow skylights to be spaced further apart, thereby reducing installation costs and minimizing risks associated with roof penetrations.
   - Modular light wells are desirable due to cost and performance predictability and better finish appearance.
   - Light wells substantially reduce the solar heat gain through the bottom of the light well, but a substantial fraction of heat goes sideways through the light well.
   - There is a market interest and demand for modular skylight products and design recommendations.
2. Lay-in Insulation: T-bar ceilings are ineffective as a pressure or infiltration barrier in a building. Completed analysis was used in Title 24 2005 Standards process to justify eliminating lay-in insulation as an option for dropped ceilings.
3. Skylight Testing: 1) Research results confirmed the benefit of light wells and insulation on light wells for reducing solar heat gain through the skylight system. 2) The effective visible transmittance (EVT) of projecting (dome) skylights stays nearly constant over a range of solar angles, whereas the EVT of flat-glass skylights rapidly drops off as solar elevation decreases. 3) National Fenestration Rating Council (NFRC) test methods for U-

factor need to be updated for projecting skylights. 4) The NFRC method of rating the transmittance of tubular skylights overestimates the transmittance of these devices for most of the year and creates an uneven playing field between tubular skylights and projecting unit skylights. 5) Photometric data can be produced for skylight systems.

4. Market connections: 1) Several lighting software developers are investigating adoption of the photometry data. 2) The research team used the photometry results to establish in the Title 24 2005 Standards a definition of the daylit zone and skylight spacing criterion.

Description of Element 6 – Integrated Design of Residential Ducting & Air Flow Systems:
The purpose of this element is to reduce energy losses from residential HVAC duct systems. The project team will develop detailed descriptions of at least three approaches to building houses with HVAC ducts in the conditioned space (unventilated conditioned attic, dropped ceiling, or a conditioned mechanical room in the attic). The descriptions will focus on the construction techniques and details that production builders will need to incorporate to successfully utilize each approach. Specific details needed for typical single floor, two story and townhouse homes will be developed.

Proposed Outcomes for Element 6:

1. Develop guidelines for installing ducts within the conditioned space of three housing types.
2. Document energy savings potential from putting ducts in conditioned spaces.

Actual Outcomes from Element 6:
Several project reports are available (www.energy.ca.gov/pier/buildings/projects/400-99-013-1.html), with major findings including:

1. Building houses with ducts in conditioned space is technically feasible and can be done at fairly small cost increments with valuable returns in energy savings and delivered comfort.
2. Three approaches are recommended for constructing California houses with ducts located in conditioned space: 1) A "Dropped Ceiling" within portions of the house to contain the ductwork. 2) A "Cathedralized Attic" design that moves the insulation to the roof plane and removes attic venting, creating a semi-conditioned space above the ceiling. 3) The Plenum Truss approach, which uses a modified scissors truss to create space for the ducts between the ceiling and the bottom chord of the truss that is then inside the conditioned space.
3. Cost impact to the builder is 0% to 3% of construction costs. Of the three recommended approaches, the Dropped Ceiling and Cathedralized Attic designs will result in the lowest construction cost increase, ranging from zero to 1% respectively. The Plenum Truss approach is estimated to add between 1.5% and 3% to construction costs. In addition, the three approaches may, in some cases, allow the heating and cooling equipment to be downsized, which could offset some of the construction cost increases or even result in an overall decrease in construction costs.
4. Significant energy savings and energy-cost savings can be achieved by building houses with ducts in conditioned space. The approach used—Cathedralized Attic, Dropped Ceiling, or Plenum Truss—has less of an impact on savings than does the house size or the climate.

Description of Element 7 – Outdoor Lighting Baseline Assessment:
The purpose of this element is to conduct a baseline survey of current outdoor lighting technologies and their usage in buildings, parking areas, walkways and signage (not including roadway lighting) in California and to develop recommendations for improving outdoor lighting

system energy efficiency. The goals of this element are to estimate the amount of energy currently used by outdoor lighting in California and evaluate its environmental impacts.

Proposed Outcomes for Element 7:

1. Develop a baseline of outdoor lighting energy usage and key environmental factors that can be used to measure the impact of any code revisions.
2. Identify potential improvements in California's Title 24 building standards or Title 20 appliance standards or the design of new utility energy conservation programs.

Actual Outcomes from Element 7:

The California Outdoor Lighting Baseline Assessment report (publication number: P500-03-082-A18) is complete with major findings including:

1. Statewide commercial and industrial outdoor lighting annual energy consumption is estimated to be 3,067 GWh (roughly 3% of the total statewide nighttime annual energy consumption).
2. Statewide commercial and industrial outdoor lighting annual energy consumption is estimated to be 809 MW (roughly 3% of the peak nighttime load).
3. Energy savings potential from replacing all California high pressure sodium (HPS) lamps with metal halide (MH) lamps would save approximately 204 GWh annually.

The project results were used in justifying portions of the outdoor lighting component in the proposed Title 24 2005 standards.

Investigation of Secondary Loop Supermarket Refrigeration Systems

Contract #: 500-98-039
Contractor: Southern California Edison
Subcontractors: Foster-Miller
Contract Amount: $300,000
Match Amount: $150,000
Contractor Project Manager: Ramin Faramarzi (626) 633-7168
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Project Description:
The purpose of this project was to investigate an advanced secondary loop refrigeration system for supermarkets. The system circulates a refrigerated brine solution from a chiller to refrigerated display cases. The project identified system improvements such as variable-speed pumping, evaporative condensing, and low-head pressure operation that reduce energy consumption. Secondary loop refrigeration systems can significantly reduce the refrigerant charge in supermarkets, which promotes substantial environmental benefits by protecting the ozone layer and inhibiting global warming caused by loss of refrigerant from the notoriously leaky systems.

This project supports the PIER Program objectives of:
- Improving environmental and public health costs/risk of California's electricity by demonstrating an alternative refrigeration system which uses less ozone-depleting refrigerant.
- Improving the energy cost/value of California's electricity by lowering electrical consumption of supermarket secondary loop refrigeration systems.

Proposed Outcomes:
1. Reduce energy consumption for refrigeration or freezing in supermarkets by approximately 13.9 percent compared with a typical multiplex system.
2. Achieve refrigerant losses at least 15 percent less than baseline system.
3. Reduce overall maintenance costs compared with baseline system.

Actual Outcomes:
1. Reduction in energy consumption for refrigeration or freezing in supermarkets by approximately 13.9 percent compared with a typical multiplex system. Reduction of nearly 5% in comparison with state-of-the-art multiplex systems.
2. Lifecycle refrigerant losses likely at least 15 percent less than baseline system, though this could not be ultimately evaluated in the timeframe of the project.
3. Overall reduction in maintenance costs compared with baseline system.

Project Status:
The refrigeration equipment display cases in a supermarket in Valencia were instrumented to measure baseline performance. A second store in Thousand Oaks with the advanced secondary loop system was also instrumented, and the performance and energy consumption of each system were monitored and compared. Monitoring and analysis proceeded through 2003. A final report was delivered in early 2004.
Final Report Title: Investigation of Secondary Loop Supermarket Refrigeration Systems
Publication Number: 500-04-013
Publication Date: March 2004
PIER Web Location: www.energy.ca.gov/pier/buildings/projects/500-98-039-0.html

Lighting Research Center Partners Program Membership

Contract #: 500-01-011
Contractor: Rensselaer Polytechnic Institute
Contract Amount: $150,000
Contractor Project Manager: Jennifer Brons (518) 687-7136
Commission Contract Manager: Steve Williams (916) 654-4050
Status: Completed

Project Description:
Membership in the Lighting Research Center (LRC) from 2002 through 2004 allows the California Energy Commission (Commission) to leverage public benefit research expenditures for maximum benefit by combining Commission funding with other members' funding. This Commission funding will support specific research as well as developing and implementing public interest RD&D policies and programs that encourage well-functioning energy markets through advancements in science and pre-competitive technologies that promise to enhance California's economy and/or environment.

This project supports to the PIER program objectives of:

- Improving the reliability/quality of California's electricity system during peak load times by helping reduce lighting loads.
- Improving environmental and public health cost/risks of California's electricity by reducing harmful nitrogen oxides (NO_x) emissions and carbon dioxide (CO_2) emissions resulting from electricity generation.

Proposed Outcomes:
As a result of membership participation in LRC, the California Energy Commission realizes the following direct benefits:

1. Priority response and advice on technical issues to Commission staff.
2. Access to a special restricted area of the LRC's web site that posts research and market information only available to members.
3. Complimentary advance copies of publications, reports and papers resulting from LRC research activities.
4. Commission staff invitations to LRC conferences, seminars and workshops.
5. Priority consideration to the Commission's request for research to be conducted in a specific area or direction within the scope of the LRC's research program that would be beneficial to the State.
6. Annual project updates and status reports.
7. Privileges to obtain information through bibliographic and database searches, and the use of LRC's Lighting Library, which includes a complete set of LRC faculty and staff publications.
8. A 33 percent discount on LRC publications for future projects the Commission may choose to invest in with LRC.
9. A 15 percent discount on research projects and help with finding facilities and co-funding for future projects the Commission may choose to invest in with LRC.
10. A 20 percent discount on any programs offered through LRC Outreach Education Program projects the Commission may choose to invest in with LRC.

11. Commission staff participation in the annual LRC Partners meeting on Rensselaer's campus, providing opportunities to:
    - Meet and network with public and private sector leaders who have a national reputation in lighting.
    - Discuss LRC research and development achievements.
    - Provide input and direction for future research activities.

In addition to the benefits that accrue directly to the Commission from this agreement, the following benefits will be made available from LRC to all entities that implement California's public goods lighting programs. Requests from public goods administrators for these benefits will be directed through the Commission to the LRC.

1. Access to a special restricted area of the LRC's web site that posts research and market information only available to members.
2. Complimentary advance copies of non-proprietary publications, reports and papers resulting from LRC research activities.
3. Product testing and consulting services at cost.
4. Privileges to obtain information and copies of faculty and staff publications through Bibliographic and database searches using the LRC Librarian, and the LRC's Partner-only web site, one set of NLPIP and DELTA publications, and LRC published books. Additional copies of publications may be purchased at the 33 percent Partner discount.
5. A 33 percent discount on LRC publications for future projects the Commission may choose to invest in with LRC.
6. A 15 percent discount on non-proprietary research projects and help with finding facilities and co-funding for future projects the Commission may choose to invest in with LRC.
7. A 20 percent discount on any programs offered through LRC Outreach Education Program projects the Commission may choose to invest in with LRC.

Actual Outcomes:
LRC assisted Commission staff with various technical investigations on approximately 45 occasions from 2003-2004. LRC staff visited the Commission five times during this period, holding four technical updates on LRC research projects. Commission staff attended LRC's Partner's Day in 2002 and 2004. In addition, the Commission and LRC developed collaborations on a number of other research efforts funded through other contracts including the Lighting Research Program, Daylight Dividends Program, and National Lighting Product Information Program. LRC resources are available at:

⇒ www.lrc.rpi.edu.

Project Status:
This contract is completed. The Commission is currently in the process of funding continued Partner's Program participation for 2005-2007.

Removing the Key Technical Barrier to the Widespread Use of Advanced Absorption Cooling

Contract #: 500-98-029
Contractor: Gas Technology Institute
Subcontractors: Stanford Research Institute : Broad USA
Contract Amount: $690,178
Match Amount: $235,000
Contractor Project Manager: Kevin Krist (847) 768-0793
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Project Description:
The purpose of this project is to improve the efficiency and lower the cost of natural gas-fired absorption chillers. This project will study and support development of new corrosion resistant materials using a fluidized-bed furnace diffusion process. The new materials are expected to enable higher temperatures and efficiencies in an advanced absorption chiller, which will be tested and demonstrated as part of the project.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by reducing the demand on the electrical system during summer peak hours.
- Improving the environmental and public health costs/risks of California's electricity by using an absorption cycle that does not use CFCs (chlorofluorocarbons) or any other material with ozone depletion, global warming, or health hazard potential.

Proposed Outcomes:

1. A direct fired gas absorption chiller with the following features:
    - Coefficient of Performance (COP) of at least 1.6.
    - Temperature limits of at least 285 degrees C (545 degrees F).
    - Thermal conductivity of coated materials equal or better than base material.
    - Materials lifetime at least 20 years.
    - Corrosion rate of less than 01 mpy.
    - Coating cost of less than $10/ft2 for generators and less than $3/ft2 for absorber heat exchangers.

Actual Outcomes:

1. Intermediate products meeting the required specifications were produced, but not in the exact size and quantities required to build a chiller.

Project Status:
The original process was developed and validated using sub-scale samples at Stanford Research Institute in Menlo Park. Quality Heat Treatment (QHT) of Australia, a leader in fluidized bed technology, worked to scale up the technology to enable full size tube production. This was found to be more difficult than anticipated because of differences between reactor materials and heating methods. QHT did very nearly produce tubes within specification, but ultimately decided to terminate the project due to financial constraints. Broad, the world's highest volume maker of absorption chillers, was ready to test the tubes in a triple-effect generator at their facility in China. The coating technology may eventually be used in other corrosion prone applications, such as condensing gas furnaces.

Final Report Title: Removing the Key Technical Barrier to the Widespread Use of Advanced Absorption Cooling
Publication Number: 500-04-019
Publication Date: February 2004
PIER Web Location: www.energy.ca.gov/pier/buildings/projects/500-98-029-0.html

BLDGS Projects Completed in 2003

Advanced Duct Sealant Testing

Contract #: 500-01-002
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $260,000
Contractor Project Manager: Max Sherman (510) 486-4022
Commission Contract Manager: Philip Spartz (916) 654-4592
Status: Completed

Project Description:
The purpose of this project is to conduct laboratory testing and field research on duct sealing products. This research will ultimately lead to and support an American Society for Testing Materials (ASTM) standard for performance testing of the durability of duct sealants. Once a national testing standard is in place, California's Title 24 codes can be updated to refer to this performance standard. A more immediate use of this work will be to test new, advanced duct sealant products being introduced into the California home building market. This work will confirm whether or not these products meet the recently revised Title 24 code requirements for duct sealing, and, from a research perspective, the work will improve future products by understanding how current duct sealing methods fail over time.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by improving the efficiency of HVAC distribution systems, thereby reducing energy costs to homeowners.
- Improving electricity reliability/quality/sufficiency of California's electrical system by reducing the peak demand within the residential sector, especially in new homes that are being built predominantly in hot inland climates.

Proposed Outcomes:

1. Enable the Commission to implement results of duct sealant longevity tests into the latest Residential Building Energy Efficiency Standards, after testing existing UL 181B-FX rated tape products using a revised method.
2. Understand what UL 181B-FX high temperature (baking) test results mean for use in California HVAC duct applications.
3. Understand what new duct sealant product behavior test results mean for use in California HVAC duct applications.
4. Develop a standardized test method for evaluating duct sealant durability (under the auspices of the American Society for Testing and Materials (ASTM)).
5. Future versions of California's Building Energy Efficiency Standards will be able to reference an ASTM standard for duct sealant longevity for all duct-sealing products used in California buildings.
6. Other public energy efficiency programs, as well as private duct sealing practitioners, will be able to use the ASTM standard and the results of the product testing to successfully plan and implement duct sealing in California buildings.

Actual Outcomes:

1. Lawrence Berkeley National Laboratory (LBNL) researchers conducted a duct sealant longevity test at constant pressure and temperature (194°F) starting in January, 2002. The five tapes tested had not failed after 16 of a total of 24 months of testing in the core-to-collar application. If the tapes do not fail after 24 months are complete, they may be considered suitable for this application.

2. None of the five tapes tested are acceptable for collar-to-plenum connections and the Title 24 Standards should not allow this application.
3. One of the five tapes tested using the UL 181B-FX high temperature (baking) test was acceptable - the new duct sealant, a foil-butyl adhesive product.
4. Because of failures observed during this series of testing, only metal clamps should be allowed for use in duct core-to-collar connections until more non-metallic clamps are evaluated.
5. An ASTM draft standard was developed to standardize test procedures and increase reliability of testing. This standard, ASTM E2342-03, was approved in December, 2003.
6. In order to complete the 24 months of testing, research begun under this contract will be completed under a separate work authorization. Commission staff will then incorporate the results of the duct sealant longevity tests into their implementation strategies for the latest Title 24 Residential Building Energy Efficiency Standards.
7. Future versions of California's Title 24 Building Energy Efficiency Standards and other energy efficiency programs will be able to reference the ASTM standard for duct sealant longevity of duct-sealing products used in California buildings.

Project Status:
The project has been completed.

ARTI Membership

Contract #: 400-99-020
Contractor: Air Conditioning & Refrigeration Technology Institute
Contract Amount: $300,000
Contractor Project Manager: Mark Menzer (703) 525-8800
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
Membership in the Air Conditioning & Refrigeration Technology Institute (ARTI) allows the California Energy Commission (Commission) to leverage public benefit research dollar expenditures for maximum benefit by combining Commission funding with other members' funding. The Commission's funding supports specific research as well as developing and implementing public interest RD&D policies and programs that encourage well-functioning energy markets through advancements in science and pre-competitive technology that promise to enhance California's economy and/or environment.

The targeted subcommittees (focus areas) selected by Commission staff for research and development funding are:

- Equipment Energy Efficiency
- System Integration
- Indoor Environmental Quality

As a result of membership participation in ARTI, the California Energy Commission realizes the following benefits:

- Participate, as a voting member of the ARTI 21-CR Steering Committee and, as a voting member, may be involved in all tasks of the Committee. The Steering Committee directs the overall effort, establishes procedures, assigns priorities and approves projects for support. The Commission may target up to 50 percent of Commission-provided funding for those specific research projects that the Commission determines to have the greatest potential for reducing energy consumption.
- Participate in the 21-CR subcommittee meetings, as agreed with the subcommittee chairs, and receive minutes of subcommittee meetings as requested. The subcommittees identify and prioritize research needs and provide recommendations to the Steering Committee. In addition, the subcommittees will make contractor selections and monitor research progress.
- Receive quarterly reports and all items sent to the Steering Committee. These items may include status reports of ongoing research projects, notices of planned site visits to contractor meetings, and draft research reports.
- Access to all research deliverables prior to public release and on-line communication services via the ARTI web site. These deliverables may include reports, analytical tools, databases and other products developed in the research projects.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity system during peak load times by helping to improve air conditioning system efficiency.
- Improving environmental and public health cost/risks of California's electricity by reducing harmful NO_x emissions and CO_2 emissions resulting from electricity generation.

- Maximizing California's market/economy connection because approximately 12 percent of all air conditioners manufactured by ARTI members are shipped to California. California is the biggest market for air conditioners in the country, and improvements in the technology will directly benefit California's electric customers.

Actual Outcomes:
At the end of the Commission's funding support the 21-CR program completed the following 12 research projects co-funded by the Commission:

1. The Efficiency Limits of Water Vapor Compressors Suitable for Air-Conditioning Applications (Project 605-10010).
2. Microchannel Heat Exchangers with Carbon Dioxide (Project 605-10020).
3. Evaluating the Performance of Thermoacoustic Cooling (Project 610-10040).
4. Evaluating the Ability of Unitary Equipment to Maintain Adequate Space Humidity Levels (Project 605-20010).
5. High Performance Heat Exchangers for Air Conditioning and Refrigeration Applications (Project 605-20020).
6. State-of-the-Art Review, Whole Buildings and Building Envelope Simulation and Design Tools (Project 605-30010).
7. State-of-the-Art Review, HVAC Component and System Simulation and Design Tools (Project 605-30020).
8. Energy Savings Potential of Flexible and Adaptive HVAC Distribution Systems for Office Buildings - Phase I (Project 605-30030).
9. Defining the Effectiveness of UV Lamps Installed in Circulating Air Ductwork (Project 610-40030).
10. Investigation of Building Exhaust Air Re-Entrainment Into Outdoor Air Intakes of Packaged Outdoor HVAC Equipment - Phase I (Project 610-40040).
11. Assessment of the Commercial Implications of ASHRAE A3 Flammable Refrigerants Used in Air Conditioning and Refrigeration Systems (Project 610-50025).
12. Study of the Effects of Water in Synthetic Lubricant Systems and Clathrate Formation (Project 610-50035).

See the project web site (http://www.arti-21cr.org/) for more information specific to each of these projects or to download the final reports.

Project Status:
The Commission's membership ended at the end of 2002 and was not renewed.

Center for the Built Environment (CBE) Membership

Contract #: 500-01-001
Contractor: Regents - Berkeley
Subcontractors: Armstrong World Industries : Arup : California Department of General Services : EHDD Architecture : HOK : Keen Engineering : NBBJ : Pacific Gas and Electric Company/Pacific Energy Center : Skidmore, Owings & Merrill : Tate Access Floors, Inc. : Taylor Engineering Team : The Trane Company : United States Department of Energy : United States General Services Administration : United Technologies Corporation : Webcor Builders Team : York International Corporation
Contract Amount: $52,500
Contractor Project Manager: Karen Roy (510) 643-8898
Commission Contract Manager: Philip Spartz (916) 654-4592
Status: Completed

Project Description:
California Energy Commission membership (from 10/02/01 to 06/30/03) in the university/industry/government research collaborative known as the Center for the Built Environment (CBE) enabled public funds to be leveraged for greater benefit to the citizens of the state. This collaborative, based on the University of California, Berkeley campus, performs research in the areas of energy efficiency in buildings, comfort for building occupants, indoor air quality, and productivity-conducive building environments. CBE generates beneficial building and human response data for dissemination to architects, designers, mechanical and building engineers, government agencies, and other entities that create indoor environments through a variety of research projects.

This project supports the PIER Program Objectives of:

- Improving energy cost/value of California's electricity by encouraging energy efficiency in the heating, cooling ventilation and lighting of buildings.
- Improving the environmental, public health and safety aspects of California's electrical supply by reducing pollution associated with electricity generation through encouraging the efficient use of energy in buildings and providing more comfortable and healthier indoor environments by improving indoor air quality.

Proposed Outcomes:
As a result of membership in CBE, the California Energy Commission benefits through:

1. Attendance at semi-annual Industry Advisory Board meetings, providing opportunities to help direct current and future research that may impact California buildings and further energy efficiency.
2. Direct connection with private industry and government leaders who are interested in promoting more efficient building technologies.
3. Semi-annual project updates and copies of papers written by CBE researchers.
4. Prioritized response and technical advice from CBE experts in areas such as underfloor air distribution, operable windows and ventilation impacts on productivity.
5. Access to the members-only section of CBE's website, which contains most recent papers and other information not available to the public until after a certain time period passes.

Membership in CBE allows the Commission to leverage public-benefit research dollar expenditures for maximum benefit by combining Commission funding with funding provided by other industry and government members (called partners). The Commission's funding supports specific research as well as developing and implementing public interest R&D policies and

programs that encourage well-functioning energy markets through advancements in science and pre-competitive technology that promise to enhance California's economy and/or environment.

Actual Outcomes:
Six of CBE's sixteen projects during this period dealt with a heating, ventilating and air conditioning strategy known as underfloor air distribution (UFAD). This strategy may result in improving both energy and facility management efficiencies for commercial buildings. The research projects were titled UFAD Case Studies, UFAD Cost Analysis, UFAD Capitol East End Block 225, UFAD ASHRAE Design Guide, UFAD Plenums and UFAD Stratification. Due to these various efforts, CBE has become an 'expert center' nationally for those involved in underfloor air distribution. California also has more buildings using UFAD than any other state. This membership in CBE revealed the need building engineers have for further development work in designing UFAD systems and precipitated PIER contract #500-01-035, Modeling for Under Floor Air Distribution.

Other CBE research during this membership period included projects on High Performance Facades, Mixed Mode Buildings, Occupant Feedback, Operable Windows, Satisfaction Survey, Speech Privacy, Team Space, Thermal Comfort Model, Ventilation/Productivity and Wireless Sensing.

Some specific results from these projects include: development of an underfloor air system design guide (now published by ASHRAE), presentation of numerous technology transfer seminars on UFAD, some web-enabled survey tools available to CBE members and the building industry at large (Occupant Indoor Environmental Quality (IEQ) Survey Operation and Maintenance (OM) Survey see more at http://www.cbe.berkeley.edu/RESEARCH/briefs-survey.htm and development of wireless sensing and control technologies for commercial building applications.

CBE's website (http://www.cbe.berkeley.edu/) gives detailed project information and many papers online. Industry Advisory Board (member) meetings were held at UC Berkeley on Oct. 18-19, 2001, Apr. 18-19, 2002, Oct. 17-18, 2002 and Apr. 24-25, 2003.

Project Status:
The project has been completed.

Commercial Buildings Cool Roofs Monitoring

Contract #: 400-00-039
Contractor: Lawrence Berkeley National Laboratory
Subcontractors: Davis Energy Group, Inc.
Contract Amount: $305,000
Contractor Project Manager: Richard Wilson (510) 486-7391
Commission Contract Manager: Philip Spartz (916) 654-4592
Status: Completed

Project Description:
The purpose of this project is to determine the savings associated with commercial cool roof systems by monitoring the actual performance of a carefully selected assortment of buildings participating in the Commission's AB970 Peak Load Reduction, Cool Communities (Cool Roof Retrofit) Program. The selected buildings must be scheduled for re-roofing and meet the criteria for project data collection purposes. Monitoring buildings is necessary to produce data that will help researchers better understand the peak savings resulting from the application of a cool roof.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by reducing peak demand plus the associated higher costs of supplying/purchasing energy during constrained periods.
- Improving the reliability/quality/sufficiency of California's electrical system by reducing peak demand.

Proposed Outcomes:

1. Increased knowledge of the peak and energy savings achievable with cool roof applications.
2. Improved building energy simulation capabilities in the area of roof heat transfer.

Actual Outcomes:

- Difficulty in finding appropriate representative candidates for cool roof retrofitting was encountered, and this delayed project progress. Building selection was based on the following criteria: single-story building, roof area between 9,000-200,000 $ft^2$2, no roof insulation to be added during re-roof and air conditioning used between June–September. After interviewing over 100 potential participants, seven commercial buildings were recruited for base-case comparison monitoring prior to re-roofing. These buildings were: a Sacramento retail building, a San Diego elementary school building, a Fresno-area fruit-packing complex (industrial, warehouse, and cold-storage buildings - equivalent to four structures) and an Irvine office building. The last building was never re-roofed, however, so data on only six of the commercial buildings could be monitored after retrofitting.
- Using the difference of average outdoor and indoor temperatures, preliminary results for the retail store building in Sacramento show estimated energy savings at approximately 50%. The school building in Richland was more difficult to estimate due to scheduling and operation issues, but initial savings were estimated at around 15% - estimates of energy savings and peak demand reduction. The cold storage facility operation in Reedley (near Fresno) is highly seasonal and re-roofing didn't occur until late in their season, so more data was collected in the following season to clarify the situation at this site with four different types of buildings. Preliminary results at this facility are estimated in the area of 20%.

- Building energy simulation capabilities to predict roof heat transfer from the data collected in this project for use in projecting energy savings in other California building are also part of the separate work authorization.
- The expected research could not be completed within the term of this contract due to difficulties in locating appropriate building sites. After discussions with the contractor and after considering the uncertainties associated with the project timeline, staff chose not to initiate a no-cost time extension to this contract. The uncompleted analyses will be completed under a separate work authorization.

Project Status:
The project has been completed.

Cooling Solutions

Contract #: 500-00-022 **Project #:** 6
Contractor: Gas Technology Institute
Project Amount: $100,000
Match Amount: $900,000
Contractor Project Manager: Kevin Trim (847) 768-0976
Commission Contract Manager: Chris Scruton (916) 653-0948
Status: Completed

Project Description:
The purpose of this project is to promote the use of gas cooling technologies. Gas cooling can provide an alternative to increased peak demand for electricity for commercial cooling, particularly in the high-growth areas of California's hot, dry valleys. Applicable technologies are both absorption cooling and gas-engine-based vapor compression cycles. The use of heat which would ordinarily be wasted is another potential application of absorption cooling. However, the initial costs must be driven down by RD&D and demonstrations conducted to allow commercial building architects, builders, engineers, and other decision makers the opportunity to see advanced gas cooling equipment "in action."

This project supports the PIER Program objectives of:

- Improving the reliability and quality of California's electrical supply by reducing summer peak demand.
- Improving energy cost by encouraging the use of natural gas during the summer when gas prices are lower, and improving the value of energy by providing cooling from waste heat sources.
- Providing greater choices for California consumers by providing new options in air conditioning technology.

Proposed Outcomes:

1. Perception barriers related to Buildings Combined Heat and Power (BCHP) will be reduced.
2. Decision makers will become informed through a BCHP economic study and computerized BCHP screening tool.
3. HVAC designers will be educated about gas cooling.
4. Members and customers will be informed about BCHP through an enhanced website.

Actual Outcomes:

1. The Gas Cooling and Desiccant Dehumidification Tutorial website update was completed and submitted for linking to CEC website.
2. Demonstrations were conducted of direct-gas-fired 5-ton ammonia absorption chillers.
3. Stirling engine assessment began and will be continued in a future research project.
4. BCHP screening tool was completed.
5. Commercial and healthcare gas cooling marketing study was conducted. The study found that there was significant potential for gas cooling and dehumidification in commercial markets, but that gas price volatility, the high price of absorption cooling equipment, and in ammonia absorbers, toxicity of ammonia are barriers to absorption cooling.

Project Status:
The project has been completed.

Energy Efficient Downlights for California Kitchens

Contract #: 500-98-020
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $648,603
Match Amount: $320,028
Contractor Project Manager: Michael Sminovitch (510) 486-5863
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
The purpose of this project is to research, develop and demonstrate a low-cost, energy-efficient compact fluorescent (CFL) downlight system designed specifically for residential kitchen applications. Kitchen lighting is the largest lighting energy user in Californian homes, accounting for one-quarter of residential lighting operating costs. Therefore, residential kitchen environments have a large energy savings potential, particularly in new construction.

Successful completion of this project is expected to result in overall lower initial costs for CFLs for kitchen lighting, making them more attractive to homeowners. Savings occur from reduced installation and call-back costs to the installers as well as lower equipment costs. In addition, a 15-25 percent increase in light output will further increase the attractiveness of CFL downlights used to illuminate kitchens, where brighter than average light is typically required for food preparation.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by overcoming technical and market issues such as lighting quality, the inability to dim and the high initial costs for CFLs that have provided barriers to the widespread use of CFLs in the residential sector.

Proposed Outcomes:

1. Use of modular electronic ballasts that control multiple CFL downlights, reducing the number of ballasts required for a typical kitchen layout of 4-6 fixtures by 75-80 percent. This new system will provide high-quality, high-performance, energy-efficient lighting with a significant decrease in initial costs over current CFL downlights.
2. Use of injection molding and other plastic molding processes to generate the complicated, optically efficient geometries that will increase efficiency by about 15-25 percent over existing CFL reflectors, which have about 50-70 percent efficiency.

Actual Outcomes:

1. Developed fixtures with a final efficacy of 50 lumens per watt.
2. Reduced fixture costs by over 50%. Comparable high performance commercial grade CFL downlights cost $150-200, while the initial target price for the kitchen lighting system (KLS) is only $50-70.
3. Found that a fully dimmable downlight system was not applicable for this project because:
   - Dimming is rarely used in kitchens common in high-production housing.
   - Adding dimming capability could as much as double the final product cost of the system.
   - The added cost of dimming was unacceptable to production homebuilders.

4. Key features of the system include:
   - *Thermally enhanced ballast configuration.* The KLS ballast has been thermally optimized by connecting it to the main metallic housing for the downlight pan itself.
   - *Master-slave ballast geometry.* This approach greatly reduces material and installation costs.
   - *Plug-and-play wire connections*. This flexible and removable connection significantly simplifies the wiring to the slave fixture.
   - *Institutionally transparent/builder-friendly*. The installation of the KLS follows the same process that builders are familiar with.
   - *High performance optics*. The reflector optics for the KLS are based on existing commercial grade CFL products that maximize output while minimizing glare.
   - *High quality CFL*. The CFLs included with the KLS are 26W high quality, high output lamps.
   - *High quality ballast*. The ballast chosen for the KLS is produced by Advance Transformer. This ballast is approved for residential applications (FCC Class B), and features a quick startup characteristic.
5. Project partner, Lithonia, is expected to release a commercial product in late 2004.

Project Status:

- The project was completed in December 2003 and the final report will be posted on the Commission web site in early 2004.
- Sacramento Municipal Utility District (SMUD) is funding a field study of prototypes at 50 area homes. This project began in late 2003.
- PIER Buildings Program is funding a follow-up project to develop a product variation optimized for retrofit applications (http://www.archenergy.com/lrp/advlight_luminaires/project_4_3.htm).

High Performance Commercial Buildings Systems

Contract #: 400-99-012
Contractor: Lawrence Berkeley National Laboratory
Subcontractors: Texas A&M University : Massachusetts Institute of Technology : University of California, Office of the President : University of California, San Diego : University of California, Berkeley : Davis Energy Group, Inc.
Contract Amount: $5,995,385
Match Amount: $3,093,049
Contractor Project Manager: Richard Wilson (510) 486-7391
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Program Description:
The purpose of the High Performance Commercial Building Systems Program is to develop and deploy a set of energy savings technologies, strategies, and techniques to help improve processes for designing, commissioning, and operating commercial buildings. The goal of this program is to reduce energy use in the California commercial sector by 22 percent by 2015. At the same time this program will strengthen the growing energy efficiency industry in California by providing new jobs and growth opportunities for companies providing the technology, systems, software, design, and building services to the commercial sector.

This program contains one administrative element and five linked technical program elements that collectively contain 14 projects with 41 distinct R&D tasks. Collectively they create a comprehensive Research, Development, and Demonstration (RD&D) program with the potential to capture large savings in the commercial building sector, providing significant economic benefits to building owners and health and performance benefits to occupants.

This programmatic contract supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by helping customers optimize their building systems to perform at peak efficiency.
- Improve the reliability/quality of California's electricity by helping lower peak electrical demand from California's commercial building sector.

A public website (http://buildings.lbl.gov/hpcbs) has been established for this research program.

Description of Element 1 – Program Administration:
This administrative element encompasses overall coordination and integration of the five technical program elements for the High Performance Commercial Building Systems program. With five subcontractors, fourteen match contributors and staff from as many organizations participating in this program, only effective management will achieve the program and project goals within allocated budget and schedule.

Actual Outcomes from Element 1:

1. Research products delivered on time and within budget.
2. Public website that communicates project results.
3. Presentations, articles and papers conveying the results of the research, provided to the buildings community.
4. The final program report, including twenty-two technical attachments, is posted on the PIER web site at: www.energy.ca.gov/pier/reports/500-03-097f.html#ExecutiveSummary

Description of Element 2 – Life-Cycle Tools:
The purpose of this element is to develop integrated information management technologies to assist in improving commercial building performance. This element is divided into three projects: Performance Metrics and Benchmarking, Retrofit Tools, and Interoperability. The three specific problems addressed in this element are related to:

- Lack of standard performance metrics and benchmarking tools and techniques.
- Lack of standard methods for retrofit performance analysis.
- Lack of standard methods for exchanging data among software programs.

Proposed Outcomes for Element 2:

1. An operational web-based benchmarking tool for commercial buildings. This tool will allow facility managers and building owners to judge their building's energy performance, compared to industry norms.
2. A building energy performance metrics tracking tool for commercial buildings. This tool will allow building operators and commissioning agents to archive, track and visualize key features of HVAC equipment operation.
3. High-speed metering proves to be an effective approach to evaluate commercial building energy performance. High-speed meter technology is commercialized in national energy communications markets.
4. A performance measurement tool for retrofit applications that will predict energy savings for potential energy efficiency measures. The tool will enable building operators and ESCOS to make informed retrofit recommendations to building owners.
5. Interoperable data schema for HVAC systems that will facilitate the exchange of HVAC system information between energy analysis tools and other building design tools. The interoperability of these building design tools will encourage architects and mechanical engineers to study the energy impacts of alternatives early in the building design process.

Actual Outcomes from Element 2:

1. The Cal-Arch tool is complete. It is a web-based benchmarking tool that incorporates California end-use data and is available on-line. It is available for public use and can be downloaded from http://poet.lbl.gov/cal-arch/.
2. Cal-Arch is regularly used at Pacific Gas & Electric's Pacific Energy Center in basic courses on energy in buildings, and can be used by energy managers, energy information system vendors, utilities, performance contractors, and researchers and analysts.
3. This benchmarking research led to enhancements and changes to the U.S. EPA-DOE Energy Star whole-building rating tool methodology, and influenced CEC and EPA policy regarding the use of benchmarking during the energy crisis in California.
4. A prototype tool was developed for defining and tracking performance metrics across the building life cycle. This "Metracker" prototype is available for download from http://buildings.lbl.gov/hpcbs/Element_2/Metracker/02_E2_Metracker.html.
5. Commercialization and collaboration discussions were initiated and continue with several potential partners who are interested in either using Metracker in demonstration pilot projects, or modifying Metracker for use in their existing and evolving software toolboxes.
6. A software tool that estimates the energy savings from commercial building retrofits (RESEM) was modernized, extended and validated for use in California. This new product, RESEM-CA, uses commercial building stock types and equipment, weather, utility rates, and preferred retrofit strategies that are specific to California. The results of the validation study confirm that RESEM-CA is a sufficiently accurate tool to be suitable for retrofit analysis.

7. The International Alliance on Interoperability's new building information model (IFC) was extended to include all critical HVAC components needed for seamless data exchange among software tools. This IFC2x2 data model was released worldwide to the public in May 2003.
8. The HVAC data model's potential use and benefits were demonstrated in a pilot exchange between a building energy simulation tool (EnergyPlus) and a duct design tool (MagiCAD) in September 2002. The demonstration showed that IFC-based data exchange can facilitate energy savings and improve the quality of design, simulation and analysis.

Description of Element 3 – Lighting, Envelope and Daylighting:
The purpose of this element is to develop an integrated building equipment communications (IBECS) network that will allow appropriate automation of lighting and envelope systems to increase energy efficiency, improve building performance, and enhance occupant experience in the space. This network will provide a low-cost means for occupants to control local lighting and window systems, thereby improving occupant comfort, satisfaction and performance. A related goal of this program element is to improve existing lighting control components and accelerate development of new daylighting technologies that will allow daylighting to be more extensively applied to a larger proportion of building floor space. This element consists of three research projects: Lighting Controls, Daylighting, and Lighting Network Operations.

Proposed Outcomes for Element 3:
1. A building equipment communications network (IBECS) that allows automation of lighting and envelope systems. The IBECS will include interfaces with controllable ballasts, wall switches, occupant sensors, electrochromic windows, Venetian blinds, and BACnet-compliant building energy management systems.
2. Software that will operate on the IBECS network to support commissioning of building lighting systems.
3. Software that will operate on the IBECS network to support lighting and envelope system diagnostics.

Actual Outcomes from Element 3:
1. Key IBECS network components were developed, including working prototypes of a ballast network interface, IBECS-enabled wall switch, advanced sensor, and lighting panel meter.
2. Two ballast manufacturers have indicated they intend to add IBECS technology to their new ballasts. In addition, negotiations are underway with a manufacturer of digital lighting networking products to embed the IBECS ballast network interface in their network connector.
3. Working prototypes of key IBECS network components were developed, including control device interfaces for three window components: DC-motorized Venetian blinds or roller shades, AC-motorized blinds or shades, and electrochromic windows. Window brightness control and interior daylight levels were improved with dynamic window control.
4. A fully-configured IBECS network was developed and piloted in an office building.
5. The IBECS technology is compliant with IEEE standards. The IEEE 1451 Standard on Sensors and Actuators has adopted for its reference protocol the same digital communications protocol (1-Wire™ communications protocol from Dallas Semiconductor) used by the IBECS system.
6. A conceptual framework was developed that unifies not only IBECS and BACnet, but also the DALI protocol that is finding increased acceptance in the lighting industry.

Element 4, Low Energy Cooling:
Description: The purpose of this element is to identify and evaluate appropriate combinations of low- energy cooling technologies, including more efficient distribution systems, and to develop the simulation models required both for this evaluation and for the design of such systems for individual buildings. This research element is separated into three projects: Appraisal of System Configurations, Efficient Distribution Systems, and Tools and Guides.

Proposed Outcomes for Element 4:

1. Increased industry knowledge of the energy and peak demand savings potential of low energy cooling technologies in commercial buildings for distinct California climate regions.
2. Building energy simulation software effectively models both individual and combinations of low energy cooling technologies.
3. The benefits of efficient duct systems are accounted for in the Title-24 compliance procedures for non-residential buildings.

Actual Outcomes from Element 4:

1. The performance of six low energy cooling systems has been evaluated for use in all sixteen California climate zones. Highlights of this analysis are (1) evaporative pre-cooling is beneficial in all California climates, and (2) radiant slab cooling can significantly reduce peak demand by smoothing and shifting cooling loads.
2. An Alternative Calculation Method (ACM) change proposal was developed to include an overall metric for thermal distribution system efficiency in the reporting requirements for the 2005 Title 24 Standards. The new metric (HVAC Transport Efficiency) is the ratio between the energy expended to transport heating, cooling, and ventilation throughout a building and the total thermal energy delivered to the various conditioned zones in the building.
3. Analysis was completed that shows duct sealing should be cost effective for VAV systems in California large commercial buildings with 10% or more duct leakage. At a suggested duct sealing cost of about $0.20/ft2 of duct surface area, sealing leaky ducts in VAV systems has a simple payback period of about 1.5 years.
4. Best practice duct-modeling principles were documented for others to use, and will be very helpful in the development of future Title-24 performance compliance methods.
5. Models were developed for mechanical and natural ventilation and wind-driven cross ventilation. These models were implemented in the U.S. Department of Energy's building thermal response simulation tool, EnergyPlus.
6. The implementation of these models in EnergyPlus will provide engineers and designers with the ability to assess the effectiveness of a number of low-energy cooling options, including natural ventilation and displacement ventilation.
7. The models have been used to assess wind-driven ventilation for the new San Francisco Federal Building and for the design of the new Children's Museum in San Diego.

Description of Element 5 – Integrated Commissioning and Diagnostics:
The objective of this element is to assemble and develop a set of manual tools, test procedures and guides to support the commissioning of HVAC, lighting and other building systems. This work will result in diagnostic procedures and commissioning tools needed by owners, operators and the commissioning industry to perform and analyze test results and operate buildings efficiently. This element's work scope is organized into three large research projects: Commissioning and Monitoring for New Construction, Monitoring and Commissioning for Existing Buildings, and Advanced Commissioning and Monitoring Techniques.

Proposed Outcomes for Element 5:

1. A library of HVAC functional test procedures for medium and large commercial building systems is widely used, resulting in improved energy performance in California buildings.
2. A commissioning and monitoring design guide proves to be an effective reference for the development of building system specifications, allowing design intent to be realized in building construction projects.
3. Fault detection and diagnosis is improved by data monitoring and visualization systems and building simulation techniques, which allows building operators, engineers and energy service personnel to make equipment operation decisions that save energy and increase equipment lifetimes.
4. Methods to employ existing EMCS for monitoring and diagnostics are developed, facilitating large energy saving opportunities in medium and large commercial buildings.
5. High-speed electric meters prove to be effective at diagnosing equipment faults and are marketed both as stand-alone meters and as integral components of EMCS.
6. Occupant feedback systems are refined and integrated with building system controls to make decisions and take actions that improve occupant comfort.

Actual Outcomes from Element 5:

1. The Control System Design Guide (Design Guide) and Functional Testing (FT) Guide for Air Handling Systems was completed. The finished product is a MS Word document that is available at: http://buildings.lbl.gov/hpcbs/Element_5/FTG/ftg-reg.php
2. The Design Guide provides methods and recommendations for the control system design process, monitoring and control point selection, and installation. The FT Guide assists users to better understand the purpose, instrumentation, test conditions, potential problems, and cost-effectiveness behind air handling system test procedures. It also describes the theory behind the tests as well as sample calculations for quantifying the energy implications of problems that commissioning can identify.
3. A comparative review of current diagnostic tools was completed and widely distributed. This report is useful to building owners and operators considering the investment in diagnostics to improve their building system's performance. A detailed set of recommendations for technical improvements and interface enhancements are included that has proved helpful to the diagnostic tool vendors.
4. A comparative review of Energy Information System tools was completed and widely distributed. This report includes a technology characterization framework that has proved useful in understanding the application of these tools for California's demand response pilot programs.
5. Three monitoring guides were completed and distributed that enable owners and building engineers to determine how their EMCS can be used to collect data needed to monitor energy performance.
6. A Non-Intrusive Load Monitor (NILM) technology was enhanced and demonstrated to show the value of high-speed metering in the automatic detection of equipment scheduling and cycling, as well as in equipment fault detection.
7. A web-based user interface for energy and maintenance systems was developed to (1) allow occupants of commercial buildings to get access to building operational data relevant to them, and (2) use information from occupants in a systematic way to improve building operations.

8. An expert system called Maintenance and Operations Recommender (MORE) was developed. MORE uses information from computerized maintenance management systems (CMMS) and energy management and control systems (EMCS) to recommend what maintenance personnel should do in response to a maintenance service request or other event requiring a maintenance or control system action.
9. A guide was developed and distributed to inform building owners, managers, and operators about strategies for improving the persistence of building performance. This guide is a practical document each persistence strategy is described in detail: why it is important, what is involved, who performs the work and what other resources are available.
10. A methodology for the rapid calibration of cooling and heating energy consumption simulations for commercial buildings based on the use of "calibration signatures," which characterize the difference between measured and simulated performance, was developed and presented in a manual.
11. The ASHRAE Simplified Energy Analysis Procedure has been evaluated in two field tests and has served to identify multiple faults in building HVAC operation and provided accurate predictions of the savings that resulted from correcting the faults.
12. A library of HVAC component models and a toolbox of software procedures to support component-level, functional testing, and performance monitoring was developed and implemented. The software is available from the HPCBS website for control and equipment manufacturers to use as a starting point in the implementation of model-based fault detection procedures in products, and for others to use in developing tools for HVAC functional testing, performance monitoring, and fault detection.

Description of Element 6 – Indoor Environmental Quality:
The purpose of this element is to demonstrate and stimulate the use of HVAC technologies and indoor pollutant source control technologies that save energy and simultaneously improve IEQ, providing a foundation for improvements in the health and learning of students. This element is composed of two related research projects: Energy Simulations and Projected State Wide Energy Savings, and Energy & IAQ Field Studies.

The research objectives of this element are to:

- Measure and evaluate energy savings, costs, and improvements in thermal comfort, indoor air quality, and noise achieved with advanced HVAC system and building interior finish material selection.
- Develop new, timely information on indoor environmental conditions in California Relocatable Classrooms (RCs).
- Evaluate the accuracy of models to predict energy consumption in RCs and upgrade computer modeling tools, and thus estimate the potential energy savings from widespread use of the energy-efficient HVAC technologies in RC and similar modular buildings.

Proposed Outcomes for Element 6:

1. Field tests of advanced HVAC technologies suitable for RCs demonstrate energy performance and IEQ improvements.
2. Field test results improve computer models, which are then used to estimate the energy savings potential for advanced HVAC technologies in RCs and other building types for a range of California climate regions. This information provides a sound basis for school districts and their consultants to save energy and improve the IEQ of California schools.
3. Volatile Organic Compound (VOC) source control measures in RCs are evaluated and the results are shared widely with RC manufacturers, promoting healthier learning and teaching environments in California schools.

Actual Outcomes from Element 6:

1. An advanced hybrid HVAC system was designed and demonstrated in California classrooms. These systems saved substantial energy, provided thermal conditioning comparable to conventional HP/AC systems, and significantly reduced indoor pollutants.
2. Statewide energy saving estimates were computed for the advance hybrid system using computer models that were validated with the actual energy performance of the demonstration classrooms.
3. Wall, carpet and ceiling material alternates were specified and incorporated into the demonstration relocatable classrooms after laboratory VOC and aldehyde source strength testing was completed for major building materials.
4. Results of the IEQ field study have stimulated the RC HVAC industry to accelerate in investing in development of new energy-efficient and IEQ-appropriate HVAC systems. The results of the building material selections have also influenced the specifications for relocatable classrooms that are used by California's Office of Public School Construction.

Project Status:

The project has been completed.

BLDGS Projects Completed in 2002

Conceptual Design Energy Analysis Tool (CDEAT) R&D

Contract #: 500-98-023
Contractor: GeoPraxis, Inc.
Subcontractors: Artifice, Inc.
Contract Amount: $452,655
Match Amount: $194,900
Contractor Project Manager: Tom Conlon (707) 766-7010
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project is to design and develop an easy-to-use, market transforming energy analysis software module (based on simulation technology) that will be seamlessly integrated with an existing 3-D conceptual building design software tool. The powerful (DOE-2 based) analysis tool will be hidden within the 3-D software tool. Target users will be energy non-experts – primarily architects, design/build contractors, developers – who will be able to generate reliable estimates of the relative energy performance of a new building in its earliest stage of design. The tool's parametric capabilities will allow users to understand and test the energy-related impacts of their designs, including fuel and material choices, system types, orientation, fenestration layout and other key decisions which often become fixed at this early stage of the construction process.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by helping architects, design/build contractors and developers generate reliable estimates of the energy performance of a building while it is still in its earliest stage of design.

Proposed Outcomes:

1. A software product that provides annual energy consumption, peak power demand, and annual energy costs for two modeled alternatives: 1) a code-complying building and 2) a "best practice" building.
2. A software product that will facilitate the estimation of building energy consumption during the early stages of architectural design.
3. Software commercialization.

Actual Outcomes:

1. Several technical and market research activities were completed that documented the design practices of building designers, including interviews, a technical colloquium, a web survey and a focus group.
2. Development of Green Building XML (gbXML) – an open data format for sharing architectural CAD data with energy analysis, facilities management, and other downstream applications (http://www.idea-server.com/gbxml.htm).
3. Development of the Energy Analysis Module (EAM) – an easy-to-use web-based energy software tool that provides a quick estimate of energy use and cost and automatically creates a robust simulation model to share with other design team members.
4. Development and marketing of a Software Developers Kit (SDK) – extensive documentation and tools to help upstream CAD firms integrate the EAM software into their applications (http://www.idea-server.com/eam_sdk.asp).
5. Demonstrated EAM interoperability with DesignWorkshop (3D CAD) and several well-known energy analysis tools: TRANE Trace 700, eQuest/DOE-2, PowerDOE, and $\text{EnergyPlus}_{\text{beta}}$.

Project Status:
This project has been completed. The software reached the alpha stage of development, with a proof-of-concept successfully demonstrated.

HVAC Distribution Systems in Commercial Buildings

Contract #: 500-98-026
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $537,000
Match Amount: $413,000
Contractor Project Manager: Mark Modera (510) 486-4678
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project is to obtain the scientific knowledge properly to measure and compare commercial buildings' thermal-distribution-system performance in terms of energy efficiency and indoor air quality. This new information will be applied to designing better thermal distribution systems in new commercial buildings and retrofitting existing systems to reduce their energy consumption and peak-electrical demand. This project will also develop and test Lawrence Berkeley National Laboratory's (LBNL) aerosol-based duct retrofit technologies to determine the extent to which they reduce duct leakage, conduction losses and energy consumption and demand. Approximately one-third of the electricity used in California commercial buildings is consumed by heating, ventilation and air conditioning (HVAC) equipment. Research suggests that the HVAC thermal distribution systems in these buildings suffer from a number of problems, such as duct leakage and thermal losses due to poor duct location.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by reducing peak summer HVAC electrical demand.
- Improving the energy cost/value of California's electricity by eliminating the waste from leaky HVAC distribution systems.
- Improving the environmental and public health costs/risks of California's electricity by improving indoor air quality through sealing HVAC thermal distribution systems.

Proposed Outcomes:

1. Characterization of large commercial building thermal distribution system performance.
2. Metrics to benchmark the performance of the thermal distribution systems.
3. Techniques for applying duct coating and sealing material in large commercial buildings.

Actual Outcomes:

1. Confirmation that duct-leakage airflows can significantly impact energy use in large commercial buildings.
2. Development of a new metric for distribution system efficiency.
3. Demonstration of a reliable test for determining duct leakage airflows.
4. Development of new techniques for duct sealing.

Project Status:
This project is complete. The results from this project will help the analysis of new requirements for commercial thermal distribution system efficiency in future revisions to California's Title 24 nonresidential building efficiency standards.

Improving Energy Efficiency of Commercial Kitchen Exhaust Systems

Contract #: 500-98-031
Contractor: Pacific Gas and Electric Company
Subcontractors: Electric Power Research Institute (EPRI) : Fisher Consulting : Architectural Engineering Corp. : International Facility Management Association
Contract Amount: $276,165
Match Amount: $225,000
Contractor Project Manager: Grant Brohard (415) 973-0106
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
The purpose of this project was to improve the energy efficiency of commercial kitchen ventilation systems by identifying optimal make-up air strategies and publishing design guidelines for the food service industry. The project team evaluated various combinations of exhaust hoods, cooking equipment, and makeup air configurations.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing more energy efficient methods for ventilating commercial kitchens.

Proposed Outcomes:

1. Demonstration that improving makeup air systems can improve energy efficiency of Underwriters Laboratories (UL)-listed commercial kitchen hoods by 40 percent.
2. Recommendation to the American Society for Testing and Materials (ASTM) for using Schlieren flow visualization system technology for the ASTM F 1704-96 Standard Test Method for Performance of Commercial Kitchen Ventilation Systems.
3. Information for possible updates to heating, ventilation and air conditioning (HVAC) design manuals by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) on commercial kitchen ventilation systems, using makeup air.
4. Comprehensive design guidelines for commercial kitchen ventilation systems.
5. Objective, visual information and analytical software on commercial ventilation equipment performance to help food service operators make informed decisions about exhaust hood design, sizing and energy efficiency.

Actual Outcomes:

1. The research team tested 214 different make-up air scenarios incorporating multiple different hood styles, make-up air configurations, different types of appliances, and varying environmental conditions. Schlieren visualization technology was employed in each case to verify effluent capture and containment at different exhaust levels. Although actual energy savings depend heavily on the specific application, one case study demonstrated a 60 percent reduction in required make-up air.
2. Team members participated in the ASTM F26 committee and influenced updates to ASTM F 1704-96 based on the research findings.
3. Research findings have informed ASHRAE Standard 154 and ASHRAE handbooks.
4. A Design Guideline based on the research findings is scheduled for Energy Commission publication in early 2003.
5. Researchers have influenced exhaust hood design and selection in many organizations, including leading fast-food restaurant chains and kitchen equipment suppliers. Outreach efforts have included statewide seminars at utility design centers, national conference

papers and presentations, and trade magazine articles. Further demonstration projects are planned with utilities through the Emerging Technologies Coordinating Council (ETCC).

Project Status:
The project has been completed and the Final Report and Design Guidelines were published in December 2002 and are available on the PIER Buildings web site (http://www.energy.ca.gov/pier/reports/500-03-007f.html). For more information see the contractor's project website (www.archenergy.com/ckv).

Next-Generation Power Management User Interface for Office Equipment

Contract #: 500-98-032
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $449,841
Contractor Project Manager: Alan Meier (510) 486-4740
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
The purpose of this project is to develop and assess energy-efficient power management interface standards adaptable to a variety of office equipment and appliances used in commercial buildings. Electricity savings from the power management of office equipment have been one of energy-efficiency's premier success stories. Despite this success, many devices that are capable of power management are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by a hardware or software conflict. The goal of this project is to capture energy savings by increasing the rate at which power management is enabled and operates successfully.

Technical challenges include identifying clear and simply interface elements and a system which meets the needs of all manufacturers. The US Department of Energy (DOE) and the US Environmental Protection Agency (EPA) have, through the ENERGY STAR Program, committed their institutional resources to ensuring the active participation of industry. The standard, however, will be voluntary – no company will be required to use it – and can be adhered to entirely or partially by manufacturers. This voluntary approach allows gaining the benefits of a standard while retaining flexibility for manufacturers that believe that they can improve on the interface, or have a product with unique or unanticipated features.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by improving the energy efficiency of commercial-sector office equipment and appliances.

Proposed Outcome:

1. A new, standard user interface for office equipment power management that is acceptable to electronic equipment manufacturers, standards organizations and the U.S. EPA's Energy Star program for voluntary adoption.

Actual Outcomes:
The project was completed in late 2002. The contractor developed a draft standard (IEEE 1621), tested the proposed components, and obtained extensive industry support for the proposed components. The contractor also established an IEEE (Institute for Electrical and Electronic Engineers) working group to get the draft standard finalized and adopted.

The draft standard includes the following components:

1. Use only three power states when possible: *On*, *Off*, and *Sleep*.
2. Use the word "Power" for terminology about power.
3. Redefine the ⏻ symbol to mean "power" as for power buttons and power indicators.
4. Use the ⏼ symbol (on/off) only when necessary.
5. Use the "sleep" metaphor for entering, being in, and coming out of low-power states.
6. Use the moon symbol — ☾ — for *sleep*.

7. Adopt "green/amber/off" color indications for power state indicators.
8. Present computer “hibernate” modes as a form of *off*.
9. Use flashing green on the power indicator for powering up and flashing amber for powering down.
10. Power buttons should toggle between the two most common power states.
11. When a device is *asleep*, pressing the power button will (usually) wake it up.

Project Status:
The project is complete. The final report and the draft IEEE standard were completed December 2002 and are posted on the PIER Buildings web site (http://www.energy.ca.gov/pier/reports/500-03-012f.html). For more information see the contractor’s project web site (http://eetd.lbl.gov/EA/Controls/).

Sustainable Building Fiscal/Economic Analysis

Contract #: 500-00-026
Contractor: State Consumer Services Agency
Contract Amount: $50,000
Contractor Project Manager: Arnie Sowell (916) 653-4090
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project is to develop a methodology for analyzing the cost effectiveness of sustainable building strategies and features. The project will develop tools that will enable the State of California to specify, design, deliver, maintain and operate sustainable buildings. These tools and methodologies must provide California's Department of Finance and the Department of General Services with defensible rationale for funding sustainable features and systems in new and retrofit state building projects.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by including energy efficiency and other sustainable building features into the valuation of state buildings, during the time when these buildings are being designed and funded.
- Improving the environment, public health and safety by incorporating sustainable building practices into state building construction processes.

Proposed Outcomes:

1. An extended life cycle cost methodology is established that incorporates sustainable building practices and features.
2. This extended life cycle cost methodology is adopted by the Department of Finance and incorporated into their capital outlay processes for new state building construction projects.
3. Other public and private building construction projects are funded by processes that incorporate this extended life cycle cost methodology.

Project Status:
This project did not proceed in a timely manner and, when the State Consumer Services Agency was ready to begin work, the term of this contract had expired. The analytical work, however, is being funded by other state agencies and is proceeding in two phases, with the first exploratory phase currently underway. The PIER Buildings program may participate in the second phase of this work, which will have the same proposed outcomes as those listed above.

BLDGS Projects Completed in 2001

A Tool for the Comprehensive Analysis of Low-Rise Residential Buildings

Contract #: 500-98-025
Contractor: Eley Associates, Inc.
Contract Amount: $216,190
Match Amount: $200,000
Contractor Project Manager: Charles Eley (415) 957-1977
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project was to develop an energy design and analysis software program to enable homeowners and members of the residential building sector to perform a variety of analyses related to energy efficiency choices in home construction, retrofits and remodels.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by helping homeowners and other members of the residential building design community generate reliable estimates of the home energy performance.

Proposed Outcomes:

1. A software product that provides annual energy consumption and annual energy costs for a variety of home envelope, equipment and system design alternatives.
2. Software commercialization.

Actual Outcome:

1. Home Energy software available at http://www.eley.com/gdt/index.htm.

Project Status:
The project has been completed.

Center for the Built Environment (CBE) Membership

Contract #: 400-99-001
Contractor: Regents - Berkeley
Subcontractors: California Department of General Services : Henningson, Durham & Richardson, Inc. : International Facility Management Association : Johnson Controls, Inc. : Lucent Technologies : Ove Arup & Partners, Ltd. : Pacific Energy Center : Tate Access Floors, Inc. : United States Department of Energy : United States General Services Administration : Alfa Tech Consulting Engineers : Critchfield Mechanical : Rosendin Electric : Webcor Builders : York International Corporation
Contract Amount: $60,000
Contractor Project Manager: Kevin Powell (510) 642-4950
Commission Contract Manager: Philip Spartz (916) 654-4592
Status: Completed

Project Description:
The purpose of this project is to allow the Commission membership privileges in the university/industry/government research collaborative Center for the Built Environment (CBE) for a two-year period from 1999 to 2001. Membership in this UC Berkeley-based collaborative to promote leading-edge commercial building design will leverage public funds for greater benefit to citizens of the state. CBE performs research on energy efficiency in buildings, comfort for building occupants, indoor air quality, and design of more-productive building environments. CBE produces information in the form of guidelines and reports for dissemination to architects, designers, mechanical and building engineers, government agencies, and other entities that create indoor environments through a variety of research projects.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by encouraging energy efficiency in the heating, cooling, ventilation, and lighting of buildings.
- Improving the environmental and public health costs/risks of California's electricity by reducing pollution associated with electricity generation through encouraging the efficient use of energy in buildings and providing healthier indoor environments by improving indoor air quality.

Proposed Outcomes:

1. Participation at semi-annual Industry Advisory Board meetings, where members from both industry and academia hear updates on the several building research projects.
2. Direct connection with building industry and government leaders interested in promoting more efficient building technologies.
3. Advance copies of technical papers by CBE researchers and access to their members-only section website area, which contains most recent papers and other information not available to the public until after a certain time period passes.
4. Prioritized response and technical advice from CBE experts in areas such as underfloor air distribution (UFAD), operable windows and ventilation impacts on productivity.

Actual Outcomes:

1. Commission staff attended the four semi-annual meetings held in October, 1999:
    - April 2000
    - October 2000
    - April 2001

2. Received project updates from CBE researchers.
3. Received technical papers on underfloor air distribution (five different projects), occupant feedback to improve building operations, speech privacy in offices, ventilation impacts on productivity, occupant satisfaction surveys and post-occupancy evaluations of buildings, and wireless measurement and control of indoor environments.

Project Status:
The CBE membership ended August 30, 2001. Funding for the CBE Membership has continued under PIER Contract # 500-01-001, approved in October of 2001. Research was on schedule and within budget. See CBE website at http://www.cbe.berkeley.edu/ for specific project information and papers.

Characterization of Framing Factors for New Low-Rise Residential Building Envelope

Contract #: 400-00-002
Contractor: Enermodal Engineering Incorporated
Subcontractors: R. Chitwood.
Contract Amount: $61,000
Match Amount: $85,810
Contractor Project Manager: Stephen Carpenter (519) 743-8777
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
The purpose of this project is to extend a national survey of current residential framing practices to include California homes. This survey, sponsored by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), will help improve the accuracy of calculating overall envelope heat loss/gain. Sixty California dwellings will be audited during construction to assess the amount of framing.

More specifically, the researchers will:

- Develop a statistically representative set of framing factors for low-rise dwellings in the State of California.
- Quantify the distribution of framing within dwellings (e.g., walls, windows, ceilings).

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by improving the energy efficiency of residential dwellings.

Proposed Outcomes:

- Revised framing factors for California homes.
- Suggestions for changes to Title 24.

Actual Outcomes:
The research team found that framing factors in California were very similar to those in the national survey and that little additional framing is used in California to meet seismic requirements. More specifically, framing factors (net of windows, doors, skylights, etc.) for new California homes are:

- 7 Percent Ceiling
- 27 Percent Wall
- 15 Percent Overall

The results are included in the proposed 2005 Title 24 revisions, which specify a 25 percent framing factor for walls.

Project Status:
The project is completed. The final report (P500-02-002) was completed in early 2002.

Increased Energy Efficiency of Refrigerators and Air Conditioners Through Use of Advanced Power Electronics

Contract #: 500-98-021
Contractor: Energy Savers International
Subcontractors: Lawrence Berkeley National Laboratory : Ed Vineyard : Hybrid Circuits, Inc. : Sun Frost : Bristol Compressors : Robert Lynette
Contract Amount: $411,614
Match Amount: $242,131
Contractor Project Manager: T. S. (Jay) Jayadev (408) 257-6465
Commission Contract Manager: Philip Spartz (916) 654-4592
Status: Completed

Project Description:
The purpose of this project was to develop an energy-efficient electronic control system by which refrigerators and air conditioners with single-phase compressor motors could be operated more energy efficiently using three-phase motors. Because three-phase motors are more efficient and less costly to manufacture, there was a significant potential for reducing the electrical consumption of conditioners and other residential appliances. In addition, this project was expected to help decrease the load energy consumption of air conditioners that have a significant effect on peak loads.

Successful completion of this project was expected to increase the efficiency of residential refrigerators by approximately 19 percent, with no increase in cost to consumers. The technology would be applicable to other residential appliances that use single-phase motors such as air conditioners, heat pumps, washing machines and clothes dryers, and promised potentially huge energy savings for such appliances.

This project supported the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by making an existing energy technology more efficient, thereby lowering the cost of electricity for cooling and electric heating to residential customers.
- Improving the reliability/quality of California's electricity by helping to reduce peak electrical demand from residential cooling.

Proposed Outcomes:

1. Development of an electronic control system that allows three-phase compressor motors to operate on single-phase electrical power. Operation with three-phase power significantly reduces electric motor conversion losses, so that the use of three-phase motors for residential applications will be economically feasible.
2. Demonstrate a 30 percent increase in efficiency for a typical domestic refrigerator compressor by improving the energy efficiency ratio (EER) from 5.4 to 7.0.
3. Demonstrate a thirty percent increase in efficiency for a typical domestic heat pump compressor.

Actual Outcomes:

1. Comparison of predicted refrigerator compressor efficiency increases (only 10 percent) and predicted unit cost did not justify designing power electronics for this application, so work was shifted to focusing on domestic heat pumps instead.

2. For domestic heat pumps and air conditioners units equipped with multiple-speed, three-phase compressor motors, efficiency increases of 30 percent were predicted, when compared to units with single-speed, single-phase motors.
3. A combined electronic power supply/three-speed controller was designed and built that easily fits inside existing cabinets of heat pumps or air conditioners this improves on mechanical multi-speed technology, which is often quite bulky.
4. The prototype combined power/controller unit proved to have a low power factor. Although adding a filter circuit would improve performance, cost factors precluded such development. A commercial power supply was used instead and research was then focused specifically on developing an electronic controller.
5. Estimated phase conversion efficiency increases for an air conditioner in going from single-phase to three-phase power were found to be on the order of 4 percent.
6. Measured speed conversion efficiency increases for an air conditioner going from single-speed to three-speed operation were about 19 percent when using the default degradation coefficient in ARI standard 210/240-94 of 0.25.
7. Estimated controller costs for residential heat pumps or air conditioners is approximately $100/ton, installed for units 5 tons and above, approximately $80/ton.
8. Laboratory testing of the heat pump electrical performance verified that lower compressor motor speed reduced unit power requirements proportionately.
9. Although full-load air conditioner operation at high temperature (105°F) did not improve unit efficiency, the controller developed through this research can operate the air conditioner at reduced speed and proportionately reduced electrical demand. For example, half-speed operation dropped power requirements from 5.5 kW to 2.5 kW.

Project Status:
This project was completed December 19, 2001. The contractor has demonstrated that power electronics can increase the energy efficiency of domestic heat pumps and air conditioners and is pursuing further market connections.

Lighting Research Center Partners Program Membership

Contract #: 400-99-017
Contractor: Rensselaer Polytechnic Institute
Contract Amount: $50,000
Contractor Project Manager: Jennifer Brons (518) 687-7136
Commission Contract Manager: Don Aumann (916) 654-4588
Status: Completed

Project Description:
Membership in the Lighting Research Center (LRC) during 2001 allowed the California Energy Commission (Commission) to leverage public benefit research expenditures for maximum benefit by combining Commission funding with other members' funding. The Commission's funding will support specific research as well as developing and implementing public interest RD&D policies and programs that encourage well-functioning energy markets through advancements in science and pre-competitive technology that promise to enhance California's economy and/or environment.

As a result of membership participation in LRC the California Energy Commission realizes the following benefits:

- Participation in the annual LRC Partners meeting, providing opportunities to help direct future research.
- Working relationships with LRC staff and industry leaders.
- Priority response and advice on technical issues to CEC employees.
- Access to a special restricted area of the LRC's website that posts research and market information only available to members.
- Complimentary advance copies of publications, reports and papers resulting from LRC-funded research activities.
- Priority consideration to the Commission's request for research to be conducted in a specific area or direction within the scope of the LRC's research program that would be beneficial to the state.
- Annual project updates and status reports.
- Privileges to obtain information through Bibliographic and database searches, and the use of LRC's Lighting Library, which includes a complete set of LRC faculty and staff publications.
- Discounts on LRC publications and research projects.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity system during peak load times by helping reduce lighting loads.
- Improving environmental and public health cost/risks of California's electricity by reducing harmful NO_x emissions and CO_2 emissions resulting from electricity generation.

Actual outcomes:
LRC staff participated in two on-site visits, updating Commission staff on lighting research and technology developments. Additionally, LRC provided:

1. A thorough technical review of the Commission's recently-released Advanced Lighting Guidelines.
2. Quick response to Commission staff questions about CFL impacts on the grid.

3. Insider information covering ongoing research such as a self-commissioning photosensor.
4. An opportunity for Commission staff to interface with the manufacturers of lighting products and to solicit industry input on lighting research issues.

Project Status:
This contract is now completed.

In October 2001 the California Energy Commission approved a $150,000 contract (#500-01-011) to extend the LRC organizational membership from 2002 through 2004.

BLDGS Projects Completed in 2000

Alternatives to Compressor Cooling

Contract #: 500-97-013 **Project #:** 3
Contractor: Regents - University of California
Project Amount: $350,000
Contractor Project Manager: Karl Brown (510) 287-3330
Commission Contract Manager: Randel Riedel (916) 654-4109
Status: Completed

Project Description:
The purpose of this project was to develop and evaluate house designs capable of providing comfort in California transition climates without the use of conventional compressor-based cooling. Compressor-based cooling is growing rapidly in transition climate zones inland from major California coastal urban centers. However, the low hours of air conditioning use in these areas create an extremely poor load factor with a substantial adverse effect on costs of service and electric system operations.

Compressor-less cooling will result in energy and peak demand savings in the warmer climate zones in California. With the highest practical market penetration, the potential avoided increase in new electric demand is estimated to be 0.5 Watt per square foot of new house area averaged across all new residential construction. The equivalent potential in retrofit is estimated to be one Gigawatt in California. Load factors would be improved with a substantial increase in system reliability and decrease in cost of service. In addition, air-conditioning system size will be reduced in more severe climates through the adoption of project design concepts.

This project supports the PIER Program objectives of:
- Improving the reliability/quality of California's electricity by reducing peak electrical demand created by compressor-based air conditioning.
- Improving the energy cost/value of California's electricity by reducing energy use and costs created by residential space cooling during summer "heat storms."

Proposed Outcomes:
1. Evaluate pilot houses and/or subdivisions using project-developed house designs.
2. Develop a prototype cost/capability-optimized alternative cooling system controller.
3. Provide technology transfer through design information dissemination, assistance, and evaluation.
4. Promote the project with design competitions.
5. Develop applications information to assist market transformation programs.

Actual Outcomes:
1. Evaluated pilot houses and/or subdivisions using project developed house designs.
   - A Northern California prototype house design was developed.
   - A Southern California prototype house was modified and a variation with street access to the garage was designed. Builders and developers in California were solicited to initiate a pilot house or subdivision program. Everyone contacted was interested in the prototype concepts and designs, but were unwilling or unable to commit to building a pilot project.
   - An expanded definition of "comfort" and the impact of Time of Use charges were both found to support the technology concept of the compressorless cooling design.

- The Northern California prototype house performance simulation was not completed so applications and sizing information is based on the results from the Southern California house. The Northern California house is expected to perform even better.
- Performance simulations demonstrated that compressorless technologies will not maintain comfort in the Southern California prototype house in all California transitional climates. However, a substantially downsized compressor (1.5 tons) operated in concert with the night ventilation and house design will maintain comfort in all transitional climate areas and in all but the most severe hotter inland climates. The performance simulations for this phase of the ACC project have been re-checked and are correct.
- Appraisers indicated that the disadvantages of a smaller compressor or no compressor would be offset by the superior construction of this particular type of residence. However, they would prefer to make their determination of energy tradeoffs based on an existing model for comparison with standard designs and construction.

2. Developed a prototype cost/capability-optimized alternative cooling system controller.
   - A prototype low energy cooling control system to enable operation of the house for night ventilation was developed and tested in two houses. The result was a demonstrated reduction in compressor cooling use while comfort was maintained in a moderately hot climate.
   - Based on occupant interviews, the user interface was successfully used by the occupants to maintain comfort and reduce compressor use during an overheated period.
   - Occupants were able to operate the controller effectively although they did not necessarily understand the technical details of the mechanical system.
   - Feedback from the controller web page simulation confirmed the usefulness of the comfort range strategy in the interface design and identified modifications to the interface that will be revised in the next phase.
3. Provided technology transfer through design information dissemination, assistance, and evaluation.
   - The PIER research team presented the house designs, control design and program concepts to many individual builders, developers, architects and owners.
   - The house designs were presented in more formal venues including: Los Angeles Depart of Water and Power in regard to Playa Vista Development, the San Diego Regional Energy Office, LBNL Noon Lecture Series, CIEE Tri-annual Review, NAHB Green Building Conference, Green Building Challenge Conference, poster session at the PIER Conference "Energy Innovations '99", and to the following individuals in Washington, D.C.: Rich Karney (DOE), Mark Ginsberg (FEMP Director), George James (Building America), Larry Zarker (PATH), Sam Raskin (ENERGYSTAR Homes, EPA), Mark Nowak (NAHB Research Center).
   - The following publications were produced: Smart Thinking About Smart Houses, and Ventilation Cooling Without Losing Control.
4. Promoted the project with design competitions.
   - In 1999, a professional slide show and script on the concepts and prototype designs were developed and presented during the "Gold Nugget Awards" held at the annual Western Building Show.
   - Two custom homes with low energy cooling, shading, thermal mass and night ventilation received the "1999 Summer Performance Awards".
5. Developed applications information to assist market transformation programs.
   - Current trends in the residential industry which are complementary with compressorless strategies provide opportunities for market adoption. These include

interest in “green buildings”, “new urbanism”, “concern for indoor air quality, health and environment”, Energy Efficient Mortgages, and the embracing of “quality” as a marketing strategy.

Project Status:
The project has been completed.

Building Design Advisor

Contract #: 500-97-013 **Project #:** 8
Contractor: Regents - University of California
Project Amount: $350,000
Contractor Project Manager: Carl Blumstein (510) 287-3320
Commission Contract Manager: Tav Commins (916) 653-1598
Status: Completed

Project Description:
This project updated the Building Design Advisor (BDA), a Windows-based computer program that facilitates decision making through integrated use of multiple analysis tools and databases. This tool, when completed, will enable building designers to consider various energy efficiency options during the design stage of new buildings, when energy efficiency measures are typically more cost effective. The main deliverable for this project was to integrate DOE-2 into the tool. DOE-2 is a building energy simulation program that is the industry standard for producing detailed and accurate energy performance simulations.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by allowing energy-saving measures to be integrated into the early design of a building, thereby making energy-efficient measures more cost effective.

Proposed Outcomes:

1. Bring the initial BDA software from an unstable, incomplete Beta release to a robust 1.0 version for distribution to academia and the building industry for evaluation and feedback.
2. Develop an updated 2.0 version with links to DOE-2. This will demonstrate the expandability of the BDA software to include links to simulation tools already accepted and trusted by the building industry and make the BDA more appealing for use in actual projects.
3. Elicit industry feedback to identify industry needs and desires, towards BDA versions that will be appropriate for use in actual projects.
4. Prepare a commercialization strategy for widespread distribution of the software with proper user support.
5. Initiate developing a BDA-based Issue Based Information System (IBIS) that will facilitate the use of the BDA as a collaborative, concurrent design tool, and greatly enhance developing links to tools that address the whole building life cycle, from design through construction and commissioning, to operation and eventual demolition.

Actual Outcomes:

1. The BDA 1.0 has been in distribution since January 1999, free of charge through the Internet. To date, more than 450 reviewers have downloaded the software from the project's Web site. Approximately 150 reviewers are from academia (professors and students) and 300 are from the building industry (architects, engineers, energy consultants, etc.).
2. Beta releases of BDA 2.0, with links to DOE-2, were used in workshops with architects and engineers in the San Francisco, Los Angeles, and Sacramento areas. Useful comments were elicited through extensive interactions between the software developers and the building industry participants. Comments and suggestions were organized and prioritized based on workshop participants input.

3. The response to the BDA concept has been enthusiastic and has resulted in very useful feedback on the specific needs of building design professionals. Several university professors plan to use the BDA software in relevant architectural and engineering courses.
4. A commercialization report was prepared.
5. The design of the BDA-based IBIS was completed, with potential use scenaria and graphical user interface elements for implementation in future versions of the BDA software.

Project Status:
The project has been completed.

CIEE Collaborative Program Planning and Management

Contract #: 500-97-013 **Project #:** 1
Contractor: Regents - University of California
Project Amount: $600,000
Contractor Project Manager: Jim Cole (510) 486-4123
Commission Contract Manager: Bill Knox (916) 654-4048
Status: Completed

Project Description:
The purpose of this project was to coordinate the efforts undertaken in the eight CIEE Transition solicitation projects. The project was to provide planning, funding, management and technology transfer activities for these projects. CIEE was the primary link between the Commission's contract managers and the principal investigators. CIEE was to ensure that the administrative and reporting requirements of each project were met.

CIEE was scheduled to release a Request for Proposals (RFP) for the first phase of a new multi-year project known as the Market Transformation Research: New Commercial Buildings Project. This new project was to have been managed by CIEE. CIEE was to maintain an Internet web site that contains information on the Commission-funded Transition Solicitation projects as well as integrate technology transfer activities into the transition project activities.

Proposed Outcomes:
1. Manage the research and development of the new end-use efficiency technologies emphasized in CIEE projects.
2. Coordinate with the research teams, the CIEE Research Board and other Sponsor representatives in exploring the initial market applications of the new energy efficiency technologies.
3. Conduct a review of the CIEE R&D program by independent peer review panel.

Actual Outcomes:
Final report for each project produced:
1. CIEE recommended the establishment of a statewide, coordinated Emerging Technologies Initiative to the California Board for Energy Efficiency (CBEE) and the California Public utilities Commission (CPUC) in June and July of 1999.
2. CIEE, in collaboration with Energy Commission staff and CIEE Sponsor representatives, prepared and issued a Request for Proposals (RFP) to select a research team and detailed research plan for the CIEE multiyear project: Market Connections for New Commercial Building Technologies.
3. CIEE collaborated with Southern California Gas and other CIEE Sponsor representatives in planning and funding two public interest R&D projects involving low NO_x, energy efficient combustion of natural gas in industrial, commercial and other market applications.
4. Independent peer review conducted in April 1999, concluded that the overall quality of CIEE's R&D program was outstanding.

Project Status:
The project has been completed.

Commercial Building Lighting

Contract #: 100-98-001 **Project #:** 7
Contractor: Electric Power Research Institute (EPRI)
Subcontractors: University of Wisconsin : Polytechnic University of New York : Los Alamos National Laboratory : National Institute of Standards and Technology : Lighting Research Center : BKI, Inc. : New Buildings Institute, Inc. : Pacific Consulting Services : Osram-Sylvania, Inc. : Lighting Ideas, Inc. : Gough & Associates, Inc. : National Council on Quantification for Lighting Pr : Illumination Engineering Society of North America
Project Amount: $24,000
Match Amount: $204,323
Contractor Project Manager: John Kesselring (650) 855-2902
Commission Contract Manager: Gary Flamm (916) 654-2817
Status: Completed

Project Description:
The purpose of this project is to guide California ratepayers to new lighting systems that reduce their energy bills and boost worker productivity and comfort. EPRI's Lighting Information Office (LIO) provides world-class, up-to-date information on lighting technologies and cost-effective training and information services. LIO insights are captured in customer-friendly formats that the Energy Commission can easily customize for delivery to California ratepayers. EPRI has produced an array of system design and analysis software that Commission staff can use in calculating the performance, costs, and benefits of lighting options for any customer's application. In addition, EPRI via this Target is directing collaborative research to define the relationship between lighting and productivity.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by increasing the efficacy of lighting sources with advanced light source technology.

Proposed Outcomes:

1. Provide advanced lighting technologies information.
2. Provide analytical tools to assess advanced lighting technology options.
3. Advance the understanding of lighting benefits and accelerate the development of advanced, high-efficiency lighting products.

Actual Outcomes:

1. Technology information.
   - New information was provided through the Lighting Information Office on energy-efficient lighting—including residential compact fluorescent lighting, electronic ballasts, LED exist signs, and outdoor luminaries. This information can be used to upgrade lighting in all California state office buildings and to consider for new standards legislation.
   - Two training sessions were offered that addressed the unique design, cost, and customer applications issues posed by new advanced lighting products.
2. Analytical tools.
   - The Commercial Desk Book software package was provided. This package provides technical, marketing, and regulatory information on lighting systems and allows users to calculate and compare annual operating costs of different technologies.

- Software support was provided for LightPAD (the EPRI lighting audit software), PowerDOE, Daylight Analyzer, and other products.

3. Understanding of lighting benefits, and development of advanced, high-efficiency lighting products.
   - A report described the effects of three different lighting configurations on office workers doing data entry tasks.
   - A publication was provided that reported on significant advances in scotopic vision. Information on the impacts of lighting on human performance can be used to ascertain whether proper light levels are being implemented in office work, and to help ensure that reduced lighting levels do not compromise human performance.
   - Research briefs were presented on basic research related to Hg-Ar and Ba as discharge light sources, which could double the energy efficiency of today's fluorescent lamps.

Project Status:
The Commission's participation in this target ended as of December 31, 1999.

Commercial Building Thermal Storage

Contract #: 100-98-001 **Project #:** 5
Contractor: Electric Power Research Institute (EPRI)
Subcontractors: Florida State Energy Center : University of Wisconsin
Project Amount: $40,000
Match Amount: $268,999
Contractor Project Manager: Mukesh Khattar (650) 855-2899
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project is to continue developing and implementing thermal energy storage (TES) technology. TES is valued for its proven capacity to trim peak power costs and reduce chiller capacity requirements, often resulting in systems more economical overall than their non-storage counterparts. This can reduce California ratepayers' electric bills and stretch California electric generation capacity. The importance of these advantages is accentuated by the emergence of refrigerant phase-out issues and real-time pricing. Many customers with facilities well suited to thermal storage are hesitant to move ahead because TES is sometimes seen as an unknown technology.

This project focuses on development of easy-to-use controls for optimal system operation, new analysis methods and data to improve the use of thermal storage in conjunction with real-time pricing, and technology demonstrations to build confidence and use of the technology.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by through development and application of thermal energy storage systems, which can reduce energy bills of California ratepayers.

Proposed Outcome:

1. Provide information to support the development, application, and commercialization of cool storage technology that is competitive with non-storage equipment in terms of efficiency and cost.

Actual Outcome:

1. Information to support development, application, and commercialization of cool storage technology.
    - A white paper was published that presented an analysis of the impacts of flexible and real-time price scenarios on the design of thermal energy storage systems.
    - Initial results were published of a field demonstration of a Near Optimal Cool Storage Controller at First Union Stadium in Philadelphia. These results can be used to analyze the viability of thermal storage for specific California sites.
    - An analysis was published of a capacity enhancement approach for chilled water thermal energy storage systems.

Project Status:
The Commission's participation in this target ended as of December 31, 1999.

Commercial Cooling and Heating Pump Applications (#1417)

Contract #: 100-98-003 **Project #:** 5
Contractor: Gas Research Institute
Subcontractors: Alturdyne : CoolTech, Inc. : Polar Works : Goettl : GTI Performing Laboratory
Project Amount: $77,100
Contractor Project Manager: Ron Edelstein (847) 768-0889
Commission Contract Manager: Brad Meister (916) 653-1594
Status: Completed

Project Description:
The purpose of this project is to develop and deploy cost-effective cooling products and maximize their market adoption and use. Major activities under this project include:

- Improved chiller performance.
- Updated state-of-the-art technologies for existing absorption chillers.
- Low-cost, engine-driven heat pump technologies for commercial applications.
- Hybrid chiller design protocols.
- Research results of advanced turbine component tests.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing cooling technologies that will reduce electricity consumption by California energy consumers.

Proposed Outcomes:

1. Hybrid Gas Engine/Electric Motor/Chiller: Development of a Hybrid Gas Engine/Electric Motor/Chiller capable of being run on either natural gas or electricity offering the customer the option of selecting their energy source. The second phase of the project will include reversing the motor to add generation capacity to the chiller for further electricity peak shaving flexibility.
2. Advanced Absorption Cooling: Develop and test a five-ton absorption-based natural gas cooling technology capable of reducing electricity demand by 5-kW per household or commercial application.
3. Gas Turbine Inlet Cooling: Novel approach to using natural gas cooling to cool the inlet air to gas turbines, increasing the available power output during hot weather. The technology envisioned will allow inlet air temperature to be dropped far lower than with conventional systems without causing turbine damage and therefore will produce significantly greater power from an existing turbine set than available with any other system. The overall effect is an increase in efficiency and a reduction in the capital cost of a turbine generating system.
4. Commercial Heat Pump: Development of a 15-30 refrigeration tons (RT) natural gas engine-driven heat pump with Goettl Air Conditioning.
5. Spray Absorption Technology: Development of technical data on spray distribution of solution for absorption chillers to ascertain technical feasibility.

Actual Outcomes:

1. Hybrid Gas Engine/Electric Motor/Chiller:
   The initial Hybrid Engine/Electric/Chiller product is now commercially available. The prototype 100-ton unit has been built with the motor to add generation capacity to the chiller for further peak shaving flexibility.

2. Advanced Absorption Cooling:
   Two laboratory prototypes were built and durability tested in the lab. Testing of one prototype in a certified test chamber has now been completed. The first test unit has been shipped to Brooklyn Union (now Keyspan Energy) for testing this summer.
3. Gas Turbine Inlet Cooling:
   The initial desiccant dehumidification alpha test was successfully completed. Discussions were conducted with a major turbine manufacturer. However, the manufacturer did not decide to pursue the Polar Works approach due to the results of the modeling effort. This work has now been wrapped up and this contract is being closed out.
4. Commercial Heat Pump:
   The development of 15, 20, 25, and 30 RT units has been completed, and those units are now commercially available.
5. Spray Absorption Technology:
   The project has been completed, and results presented to Trane. After testing the concept, Trane decided not to move forward with this concept.

Project Status:
Efforts continue as planned for the Hybrid Gas Engine/Electric Motor/Chiller and Advanced Absorption Cooling projects. The Commercial Heat Pump project was successfully completed. Technical efforts were completed on the Gas Turbine Inlet Cooling and Spray Absorption Technology projects, but work has now been discontinued because manufacturers decided not to pursue the technologies.

Commercial Heat Pump/Air Conditioning

Contract #: 100-98-001 **Project #:** 4
Contractor: Electric Power Research Institute (EPRI)
Subcontractors: Lennox Industries : ClimateMaster, Inc. : Joint Center for Energy Management-University of Colorado : Alliant Energy : Bevilacqua-Knight, Inc. : Geothermal Design & Engineering, Inc.
Project Amount: $144,500
Match Amount: $1,186,322
Contractor Project Manager: Mukesh Khattar (650) 855-2899
Commission Contract Manager: Martha Brook P.E. (916) 654-4086
Status: Completed

Project Description:
The purpose of this project is to continue developing higher-efficiency, climate-wise refrigerants for the commercial heat pump and unitary air conditioner market. In California, this accounts for approximately one-third of the commercial sector's electricity use. Manufacturers are slowly developing electric equipment for the best refrigerants emerging from research. The slow pace of equipment development is a barrier to the broader use of commercial heat pumps. This project includes developing environmentally superior heat pumps, water-loop, and geothermal systems, and improving indoor air quality and dehumidification. The target also includes work on improved refrigerants and equipment to achieve greater comfort, lower noise, and lower capital and operating costs.

This project supports the PIER Program objectives of:
- Improving the energy cost/value of California's electricity by developing and enhancing the performance and efficiency of heat pump technology for space heating and cooling applications.
- Improving the environmental and public health costs/risks of California's electricity by reducing energy use which in turn decreases power plant emissions and supporting the changeover from ozone-depleting refrigerants to zero ozone-depleting (ZODP) fluids.

Proposed Outcomes:
1. Provide practical technical information to increase the market penetration of energy efficient heat pumps and new air conditioning technologies.
2. Support development and introduction into the market of commercial heat pump products with substantially improved comfort, efficiency, and environmental impact.
3. Support development and application of Water-loop and Ground-coupled/Geothermal Heat Pump (WL/GCHP) Systems.
4. Support development and application of energy efficient and cost-effective solutions to treat ventilation air and improve indoor air quality and dehumidification.

Actual Outcomes:
1. Technical information.
   - A status review report was published on EPRI commercial heat pump innovations.
   - Updates on industry news were published on refrigerant availability, refrigerant properties, and the ASHRAE 90.1 Standard.
   - The Geothermal Information Office provided information to EPRI members on the use of geothermal systems in commercial and residential buildings.

2. EPRI teamed with Lennox International to develop the first prototypes of Zero-Ozone Depletion Potential commercial rooftop heat pumps with 7.5 and 10-ton capacities. A lab test report was published.
3. Water-loop and ground-coupled heat pump technology.
   - EPRI sponsored development by ClimateMaster of a water-source air heat pump for conditioning of 100% make-up air. The design is more energy efficient than existing units and has features for improved occupant comfort.
   - An evaluation was made of variable pumping strategies and operation of the SmartLoop Controller in buildings with water-loop heat pump systems.
   - A field test report and a tech brief were published on results of energy performance monitoring of a geothermal heat pump in a quick service restaurant.
4. A report was published providing a summary of current and advanced strategies for designing HVAC systems to meet indoor air quality requirements.

Project Status:
The Commission's participation in this target ended as of December 31, 1999.

Commercial Thermal Distribution Systems

Contract #: 500-97-013 **Project #:** 4
Contractor: Regents - University of California
Subcontractors: Lawrence Berkeley National Laboratory
Project Amount: $400,000
Contractor Project Manager: Karl Brown (510) 287-3330
Commission Contract Manager: Mazi Shirakh (916) 654-3839
Status: Completed

Project Description:
The purpose of this project was to develop information and products that would improve the energy-efficiency and performance of heating, ventilation and air conditioning (HVAC) equipment in commercial buildings. This project assessed the performance of air-duct systems in California's commercial buildings, developed and tested duct-sealant and duct-encapsulation technologies specifically for applications in commercial buildings, and developed tools to diagnose the energy-performance of commercial building fan systems.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by reducing peak demand and improving load factor, leading to reduced infrastructure costs and system reliability risks.
- Improving the energy cost/value of California's electricity by improving thermal performance of the commercial thermal distribution systems. Current data suggests that leakage in commercial thermal distribution systems is in excess of 20 percent, with additional excess energy use caused by fan system problems.
- Improving the environmental and public health costs/risks of California's electricity by improving indoor air quality through improved control of air flows and duct encapsulation technology.

Proposed Outcomes:

1. Advance knowledge about performance and losses for commercial building thermal distribution systems.
2. Evaluate the potential for reducing thermal losses through duct sealing, duct insulation, and improved equipment sizing.
3. Advances in innovative techniques for sealing ducts and encapsulating internal duct insulation.
4. Advances in protocols and techniques for testing, analyzing and diagnosing energy-related problems in large commercial building fan systems.

Actual Outcomes:

1. Identified significant duct leakage in large commercial buildings, with large associated energy losses.
2. Confirmed significant potential energy savings from duct sealing in large commercial buildings and identified building model enhancements that will allow incorporation of duct performance improvements in building energy standards.
3. Improved prototype equipment and field experience for duct sealing and encapsulation technology.
4. Made advances in tracer gas measurement techniques and refined protocols for diagnosing energy losses in large building fan systems.

Project Status:
The project has been completed.

Develop R&D Plan for PIER Buildings Team for Indoor Air Quality

Contract #: 100-98-001 **Project #:** 25
Contractor: Electric Power Research Institute (EPRI)
Subcontractors: Taylor Engineering : Building Ecology Research Group : Lawrence Berkeley National Laboratory : National Institute of Standards and Technology
Project Amount: $38,480
Contractor Project Manager: Mukesh Khattar (650) 855-2899
Commission Contract Manager: Nancy Jenkins (916) 654-4739
Status: Completed

Project Description:
The purpose of this project is to develop a comprehensive indoor air quality (IAQ) research plan, identify important gaps in this research as they pertain specifically to energy efficiency, target areas for future funding, and research, and prioritize research efforts that will specifically benefit California residents. Almost 70% of the California workforce works in non-industrial, non-agricultural indoor settings. Over the past 20 years, it has become clear that improper design, operation, and maintenance of HVAC systems have been implicated in infectious or allergic healthcare problems including increased frequency of colds and flu, hypersensitivity pneumonitis, sick building syndrome, and Legionnaires' disease. This project addresses IAQ through an interdisciplinary approach, uniting experts from several fields of study.

This project supports the PIER Program objectives of:

- Improving energy cost/value through optimizing the use of building HVAC systems and improving occupant health, productivity and comfort.
- Improving the environment and public health costs/risks of California's electricity by identifying key areas of research to mitigate IAQ-related illness and loss of worker productivity.

Proposed Outcome:

1. Identification of the highest priority research needs pertaining to the relationship of IAQ, health, occupant satisfaction, and worker performance with building energy use.

Project Status:
As of December 2000 the project was behind schedule and the Commission discontinued participation in the project.

Development of High Efficiency Lighting Torchieres

Contract #: 500-97-013 **Project #:** 6
Contractor: Regents - University of California
Subcontractors: Lawrence Berkeley National Laboratory
Project Amount: $90,000
Contractor Project Manager: Carl Blumstein (510) 287-3320
Commission Contract Manager: Mazi Shirakh (916) 654-3839
Status: Completed

Project Description:
This purpose of this project was to develop portable, high-efficiency, indirect torchiere fixtures that would use one of the next generation high-efficacy electrodeless or electroded fluorescent lamps. These fixtures are targeted at the commercial office interiors where there is a demand for high color quality and low-glare portable lighting. This proposed effort was a first step in the development and demonstration of new office torchiere lighting systems. Wide adoption of the technology developed in this project would significantly increase the penetration of high-efficiency fixtures in commercial interiors.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by improving the efficacy of the very popular torchieres. Incandescent torchieres are very inefficient and present a fire hazard. The proposed advanced torchieres reduce electrical consumption by 75 percent.

Proposed Outcomes:

1. Produce prototype fixtures that exploit the properties of the next generation of high efficiency advanced fluorescent lamps and advanced optical reflectors.
2. The prototypes were expected to have high color quality and low glare suitable for use in commercial office spaces.

Actual Outcomes:

1. The LBNL contract discusses high efficiency lamps with efficacies in the range of 83 to 100 lumens per watts. The actual outcome was lamps with efficacies in the 72 to 79 lumens per watt. The commercially available lamps currently have efficacies in the 55 to 69 lumens per watt.
2. The proposed lamps have color temperatures and color rendering indexes that are comparable or superior to what is commercially available.
3. LBNL also experimented with different types of optical reflecting materials, determining that white paint is the most practical due to cost considerations.
4. The retail costs are expected to be around $60-$70 a unit which is competitive with what is available now (which is around $50-$60 for high-end products).
5. Currently there are no torchieres with the uplight/downlight components and with the range of efficacies discussed above.

Project Status:
The project has been completed.

Diagnostics for Building Commissioning and Operations

Contract #: 500-97-013 **Project #:** 5
Contractor: Regents - University of California
Subcontractors: University of San Diego : SuperSymmetry : Stanford University : Jones Lang Wootten: California, Inc.
Project Amount: $350,000
Contractor Project Manager: Carl Blumstein (510) 287-3320
Commission Contract Manager: Joseph Wang (916) 654-4026
Status: Completed

Project Description:
The purpose of this project was to demonstrate a system that allows building occupants to monitor the energy use within their building, so they may determine if the building is performing at its optimum energy-efficiency level. This system will permit building occupants to improve the energy-efficiency of their buildings by facilitating the identification of energy performance problems.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by helping customers optimize their building systems to perform at their peak energy efficiency.

Proposed Outcomes:
This project was to demonstrate an advanced operator information, monitoring and diagnostics system (IMDS) for whole-building commissioning and operations. The system and project objectives included:

1. High-quality sensors.
2. Knowledge base to identify system failure.
3. Automated communications and data management.
4. Data visualization to diagnose building energy performance problems.
5. Evaluating the energy savings and other non-energy benefits of IMDS use. The objective is to reduce total energy use and energy cost by 15 percent without sacrificing any other building services or performance issues.
6. Developing and demonstrating techniques to automate fault detection and diagnosis using a steady-state chiller model and evolutionary programming for self-learning systems.
7. Evaluating the decision making and technology adoption processes in the commercial buildings sector.

Actual Outcomes:

1. LBNL successfully demonstrated that the IMDS is very useful in evaluating the building's performance. The building operators perceive significant improvements in the performance of the building. These include improvements in control, reduced comfort complaints, and the identification of significant energy savings. Even more significant is that the IMDS has been useful in identifying an ongoing set of problems at the building that are related to problems inherent in the control systems.
2. LBNL developed a prototype stand-alone chiller data analysis tool was developed to provide the operations staff with additional diagnostic capabilities beyond the IMDS. However, neither the chiller diagnostic tools nor the utilization techniques are mature at this point.

Project Status:
The project has been completed.

Evaluate Small Air Conditioning Units for Northern/Central California

Contract #: 500-97-010 **Project #:** 1
Contractor: Pacific Gas and Electric Company
Project Amount: $500,000
Contractor Project Manager: Lance Elberling (925) 866-5519
Commission Contract Manager: R.Michael Martin (916) 654-4039
Status: Completed

Project Description:
This purpose of this project was to:

- Identify those technologies that can potentially improve the energy efficiency of air conditioning applications using rooftop packaged air conditioners on small commercial buildings in hot-dry climates.
- Document the actual performance of two selected technologies through laboratory testing over a range of operating conditions.
- Provide this information to the HVAC market to encourage the adoption of appropriate technologies.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing electricity customers in the commercial sector with information on energy-efficient options to cool their facilities.

Proposed Outcome:

1. Identify several technologies that could potentially improve the energy efficiency of air conditioning technologies with sufficient detail to enable specifiers of equipment to make good informed choices.

Actual Outcomes:

1. Documented several such technologies, with detailed information about performance of two such technologies at a variety of outdoor temperature and humidity conditions.
2. Used evaporative condenser pre-coolers that resulted in greater energy savings in hot dry climates at greater initial cost and is recommended for retrofit applications.
3. Used conventional design high efficiency air conditioners with dual compressors which had more modest performance improvements at a lower additional first cost and is recommended for new applications.

Project Status:
The project has been completed.

Improve C/E of Building Commissioning

Contract #: 500-97-010 **Project #:** 2
Contractor: Pacific Gas and Electric Company
Subcontractors: Schiller Associates : ESS Engineering, Inc. : Joint Center for Energy Management-University of Colorado
Project Amount: $300,000
Contractor Project Manager: Steven Blanc (925) 866-5570
Commission Contract Manager: Joseph Wang (916) 654-4026
Status: Completed

Project Description:
The purpose of this project was to investigate and demonstrate cost-effective and energy-efficient methods for the commissioning of medium to large buildings that have complex mechanical, lighting, and energy management control systems. Commissioning would insure that buildings designed for maximum energy-efficiency perform as intended, thereby reducing energy costs associated with building operations.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by developing tools to analyze, and guarantee, the performance of energy-efficiency measures.

Proposed Outcomes:
A major obstacle to wide-spread adoption of building commissioning is cost. This project created commissioning techniques more effective and less costly to implement. These techniques were tested in a laboratory and a demonstration site to evaluate their performance. The system included high-quality sensors, a knowledge base to identify system failure, automated communications and data management and data visualization to diagnose building energy performance problems. In addition, the project developed:

1. Specifications for a building fault detection and diagnostics technique that would provide a platform for further commercial development and provide information needed to automate the diagnosis of building energy performance problems.
2. A commissioning tool which would focus on the identification of minimum historical data requirements necessary to accurately predict cooling system performance in a typical commercial building.
3. A measurement and verification tool that would allow users to evaluate different measurement scenarios to determine cost effectiveness for specific energy-efficiency measure.

Actual Outcomes:

1. Developed a model-independent, fault detection and diagnostics for variable air volume terminal units. This commissioning tool is based on the use of a residual approach to develop fault detection and diagnostics tool preprocessors. This avoids the traditional use of model based approach requiring that a tool be calibrated using large amount of historical data.
2. Developed a first principles model for integrated cooling systems. This tool focuses on the identification of the minimum historical data requirements necessary to accurately predict cooling system performance in a typical commercial building.
3. Developed a building automation control network (BACnet)-based control system driver to facilitate fault detection and diagnostics (FDD) in open architecture energy management control systems. This tool is a generic communications interface for controls

systems employing BACnet gateway open protocols. This allows building operators access building data with any building control systems.

4. Developed a measurement and verification value tool that is a data base-driven program that allows the user to evaluate different measurement and verification scenarios to determine cost and saving uncertainty for specific energy efficiency measures.

Project Status:
The project has been completed.

Residential Heat Pump Technology

Contract #: 100-98-001 **Project #:** 1
Contractor: Electric Power Research Institute (EPRI)
Subcontractors: D.W. Abrams : P.E. & Associates : Pacific Consulting Services : OG&E Electric Services Company : Oregon Department of Energy : Saturn Resource Management : Southern California Edison
Project Amount: $293,697
Match Amount: $1,129,818
Contractor Project Manager: Richard Myhre (510) 444-8707
Commission Contract Manager: Bill Pennington (916) 654-5013
Status: Completed

Project Description:
The purpose of this project is to support EPRI's continuing development of high-performance (energy efficient) heat pumps and their efforts to deliver quality data and services to invigorate the market. Working with manufacturers and research partners, EPRI is supporting production of climate-wise air and geothermal heat pumps, demonstrating heat pump applications, verifying performance and energy efficiency, and pursuing refinements to the "Insider" heat pump, a compact unit for multifamily and manufactured housing. This target also delivers products on duct system design and duct sealing technology to further reduce energy waste, and collaboration on a national technician certification program to address installation and customer satisfaction issues.

EPRI's collaborative program impacts technology development and heat pump infrastructure nationally. This, in turn, benefits California users to ensure a continued positive market environment for residential heat pumps. The Commission will receive technical information and persuasive promotional materials for local educational activities to stimulate residential customer's interest.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by developing and enhancing the performance and efficiency of residential heat pump technology to reduce the energy needs for space heating and cooling applications.
- Improving the environmental and public health costs/risks of California's electricity by reducing energy use, which in turn decreases power generation emissions, and by supporting the changeover from ozone deleting refrigerants to Zero Ozone Depletion Potential (ZODP) fluids.

Proposed Outcomes:

1. Provide tools to increase the use of Zero Ozone Depletion Potential (ZODP) Refrigerants.
2. Provide tools to increase the potential for the use of Air-Source Heat Pumps.
3. Provide information to support market-ready enhanced, integrated heat pumps.
4. Develop a Technician Certification program to improve the likelihood of proper heat pump selection and proper installation.
5. Supply information to increase the potential for use of Ground-Source Heat Pumps (GHP).
6. Compile information to increase the potential for use of Thermal Distribution Systems Development and Applications.
7. Conduct a Tailored Collaboration entitled "Research on Heat Pump Performance Maps for Incorporation into Building Energy Analysis Calculation Methods" to develop

improved calculation methods that permit more accurate comparison of standard air-source heat pumps and air conditioners with ground-source heat pumps.

Actual Outcomes:

1. Software and information were provided on the performance of zero ozone depletion potential refrigerants.
2. Air-source heat pumps.
   - Version 1.0 was released of EPRI's ESPRE for Windows, which can be used to analyze building energy use as a function of technology.
   - Version 3.0 was released of EPRI's Residential Desk Book, which offers a compendium of information of end-use residential technologies.
   - Brochures were published on dual fuel heating and cooling, sealing heating and cooling systems, and repairing leaky ducts.
   - A newsletter was published on heat pump developments, issues, and markets.
   - Integrated heat pumps.
   - Support was provided to the manufacturer of the PowerMiser integrated heat pump.
   - A brochure was published on marketing integrated heat pumps
   - A brochure was published on the Insider integrated heat pump.
3. EPRI assisted in the development of a comprehensive technician certification program, which merged the testing and certification programs of NATE, ACCA, and RSES.
4. Ground-source heat pumps (GSHPs).
   - A design and installation planning guide was published for GSHPs.
   - A directory was published of GSHP manufacturers and equipment.
   - EPRI hosted the 1999 GeoExchange Industry Conference and Exposition in Sacramento in September 1999.
5. A brochure was published on optimizing thermal distribution systems.
6. Detailed performance map data were collected on both air- and ground-source heat pumps for use in an upgraded analytical procedure to be used in California Title 24 residential building energy compliance evaluations. Several thousand performance maps were obtained, and recommendations were made on analytical procedure modifications.

Project Status:

The Commission's participation in this target ended as of December 31, 1999. Participation in the tailored collaboration ended December 2000.

Residential Thermal Distribution Systems

Contract #: 500-97-013 **Project #:** 2
Contractor: Regents - University of California
Subcontractors: Lawrence Berkeley National Laboratory : ConSol Consulting
Project Amount: $400,000
Contractor Project Manager: Karl Brown (510) 287-3330
Commission Contract Manager: Dale Trenschel (916) 654-4884
Status: Completed

Project Description:
The purpose of this project was to develop new knowledge and prototype technologies that would improve the energy-efficiency and performance of heating, ventilation and air conditioning (HVAC) equipment in residential buildings. The work included developing and testing the effectiveness and durability of duct sealant technologies for use in residential buildings. New methods of measuring duct leakage were evaluated, and interactions between equipment sizing and the effectiveness of the distribution system to deliver cooling throughout a home were analyzed. A significant issue investigated was the ability of downsized equipment and good distribution systems to deliver the same cooling benefits as larger, typical HVAC systems, but at a lower cost to the consumer.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing information, tools and products to reduce HVAC energy consumption in residential buildings. Specifically, this project will develop new procedures to evaluate the longevity of sealants used on residential HVAC ducts and new test methods for measuring energy losses through duct leakage. These results make possible the reduction of electricity for home heating and cooling use in residential HVAC systems through better duct sealing measures, reduced equipment sizing and improved diagnostics.

Proposed Outcomes:

1. Improve duct leakage test methods.
2. Update the American Society for Testing and Materials (ASTM) Standard E1554 – Determining External Air Leakage of Air Distribution Systems by Fan Pressurization.
3. Develop and introduce a draft ASTM standard for longevity testing of duct sealants.
4. Measure the performance of residential cooling equipment and associated distribution systems.
5. Compare the REGCAP simulation model to the measured field data.
6. Provide technical support to the Energy Commission for updating the Low-Rise Residential Alternative Calculation Method Approval Manual for 1998 Energy Efficiency Standards for Low-Rise Residential Buildings (CEC 1999) and Procedures for HVAC System Design and Installation (for HERS).
7. Support ASHRAE, ASTM and U.S. EPA duct leakage research and interface with projects funded by other agencies.

Actual Outcomes:

1. This investigation yielded a new duct leakage test called DeltaQ.
2. The existing ASTM Standard (E1554) for measuring duct leakage has been rewritten and submitted to the ASTM standards review process.
3. A draft ASTM standard for longevity testing of duct sealants was developed. A draft was submitted to ASTM subcommittee E06.41 for balloting and comment. The comments on

the draft resulted in changes to the test method and apparatus. A new test apparatus was constructed with funding from the U.S. DOE.

4. Simulations of summer temperature pulldown time have shown that duct system improvements can be combined with equipment downsizing to save first cost, energy consumption, and peak power and still provide equivalent or superior comfort.
5. Air conditioner name plate capacity ratings alone are a poor indicator of how much cooling will actually be delivered to the conditioned space. Duct system efficiency can have as large an impact on performance as variations in Seasonal Energy Efficiency Ratio (SEER). Installing high SEER units can reduce energy consumption with no apparent drawbacks.
6. Duct efficiency calculations are included in the Low-Rise Residential Alternative Calculation Method Approval Manual for 1998 Energy Efficiency Standards for Low-Rise Residential Buildings (CEC 1999).
7. Procedures for HVAC System Design and Installation (for Home Energy Raters) have been updated.
8. Field-testing has shown that standard flowhoods can be poor for measuring residential register flows.

Project Status:
The project has been completed.

BLDGS Projects Completed in 1999

Improve C/E of Building Control Systems

Contract #: 500-97-010 **Project #:** 3
Contractor: Pacific Gas and Electric Company
Project Amount: $250,000
Contractor Project Manager: Steven Blanc (925) 866-5570
Commission Contract Manager: Joseph Wang (916) 654-4026
Status: Completed

Project Description:
The purpose of this project was to investigate methods to reduce the costs of current energy-management systems, such as low-cost building control systems and sensors. Energy management systems allow utility customers to monitor and control their energy consumption and improve the energy-efficiency of the whole building.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by providing utility customers with tools that could help reduce their energy consumption.

Proposed Outcomes:

1. Develop a method for determining the accuracy and storage frequency needed for various data acquisition functions in commercial HVAC systems.
2. Specify the use of economics (costs versus benefits) and operating needs to determine accuracy and storage frequency for data collected from commercial HVAC systems.

Actual Outcomes:

1. PG&E developed a method for determining the accuracy and storage frequency required for various data acquisition functions in commercial HVAC systems.
2. PG&E demonstrated the method on an example building under two different weather profiles (focusing on the air-handling equipment and chilled water temperature) and showed the potential benefits when more accurate equipment and better diagnostic techniques are used.
3. PG&E repeated the analysis on several other building types and sizes using a different energy simulation model. The result is a range of recommended measurements, storage frequencies, and potential energy savings for buildings with different annual energy uses.

Project Status:
The project has been completed.